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OF THE

INTERNATIONAL RAILWAY ASSOCIATION

(ENGLISH EDITION)

SPECIAL ACCOUNTS

summing up the reports of the questions for discussion at the ninth congress of the International Railway Association (Rome, 1922).

(Continuation and end) [1]

SECTION III. — WORKING (OPERATION).

[656 .211]

QUESTION IX

(Terminal stations for passengers),

By L. MACCALLINI, special reporter.

1. *Scope of the question and the Administrations consulted.* — Question IX on terminal passenger stations, especially as regards the investigation of the best methods, arranging these so as to reduce the number of movements of engines and empty stock, has been dealt with in two reports, one for English speaking countries [2], and the other for the remaining countries [3]. In these reports are given details of the most important terminal stations on thirty-four railways in the following countries: South Africa, England, Australia, Canada, Scotland, United States and India; and on sixteen railways in the following other countries: Belgium, Denmark, Spain, France, Italy, Norway, Holland, Portugal, Sweden, Switzerland.

We will commence with a brief *résumé* of the most important points which appear in the two reports, and will then draw our conclusions on the two reports taken together.

2. *Importance of the subject.* — The question of the best lay-out of terminal passenger stations and the best organization of the service with a view to reducing the number of movements of engines and empty stock is of great importance, in order to increase the capacity of the stations and to ensure economical and regular working.

(1) Vide *Bulletin of the International Railway Association*, April 1922.

(2) See *Bulletin of the International Railway Association*, October 1921, p. 1483.

(3) See *Bulletin of the International Railway Association*, March 1922, p. 553.

3. *General remarks.* — The arrangement which may be best as regards simplifying and reducing shunting may give rise to conditions which are less satisfactory or even unsatisfactory from other points of view. In addition to this, local considerations generally have a very great influence on the choice of lay-out, and this accounts for the great diversity of types of stations, each one of these constituting, one may say, a special case, hence it is difficult to draw general detailed conclusions.

4. *General types of terminal passenger stations.* — In report No. 1, the stations are classified according to the arrangement of the approach lines, platform lines, and the main building under the following headings : *dead end* stations; stations with *through lines; loop* stations; stations of *combined types.*

The author of report No. 2 prefers to classify more strictly the terminal stations as: *dead end* or *through,* from the point of view of layout, and as: *end of the run* or *reversing* stations as regards the traffic working.

The dead end stations obviously give rise to the more serious difficulties as regards shunting movements. These operations are, on the other hand, much easier in the through stations and in their derivatives, the loop stations.

5. *Loop stations and tracks.* — These stations are a very interesting speciality of the American railways, which certainly have their own particular needs as regards their passenger stations. These have not as yet been adopted by the railways of other countries (1). It may be said that the lay-out of the loop tracks provides an ideal solution of the problem. It allows the direction of the train to be reversed by a simple continuous movement, without altering the marshalling and obviating the necessity of re-marshalling, detaching or turning any of the units, either engines, coaches or brake vans of which the trains are made up. This applies to the intensive working of suburban trains which need to return in the opposite direction with the least possible delay, to main line trains which are returning in the other direction, or, in general, to all movements of sets of empty stock which proceed to the carriage sidings before again being used, and also to engines returning to or coming from the shed. If one considers the difficulties which these movements give rise to in dead end stations, the great advantages of such a lay-out will be appreciated, although this arrangement requires plenty of space, and entails considerable expense.

The loop type of station affords special facilities for the location of engine sheds and carriage sidings.

Report No. 1 gives examples of the application of the loop system in some of the most modern American stations. We may specially mention the New York City Central Station, the largest in North America. This station has lines on two levels, the lower level being for suburban trains and the higher level for main line trains. Here we have a well designed combination of loop stations with dead end stations, the latter tracks being within the loop. The incoming suburban trains stop at the arrival platforms and then run round the loop to the departure platforms or the empty stock sidings, as the case may be. The dead end lines are reserved for trains that cannot be unloaded sufficiently quickly, or for departure trains. These trains, after having run round the loop, set back into the dead end lines.

The Broad Street Station and the Pennsylvania New York City Station with its Sunnyside empty stock sidings, are other characteristic examples, these being in fact through stations provided with loops to turn the trains when

(1) Except on one of the London tube railways. (*English Editor's note.*)

putting them away in the carriage sidings.

6. *Triangular lay-outs.* — Another interesting lay-out of traks which enables the shunting operations to be reduced to a minimum, as regards the marshalling of trains at dead end stations, is the triangle. This arrangement is very useful, especially on lines which make a practice of using special rolling stock and which have definite rules as to the marshalling of the trains. This arrangement has also been adopted in America, in the Joint Station at St. Louis, which is a dead end station. The triangles, which serve the two groups of platform lines, are here placed immediately in rear of the station and the trains can be turned on arrival or departure.

The triangles should be placed, whenever possible, between the station and the empty stock sidings, to avoid all unnecessary movements.

In all other countries, the arrangement of triangular tracks is only used in certain cases to meet exceptional circumstances.

The triangles are not so advantageous as the loops. Like the latter, they need considerable space.

7. *Approach lines, capacity of stations, length of platform lines, curves, and their effect on shunting operations.*—Although freedom and independence in shunting operations in a station has more effect upon the capacity and regularity of the service than upon the number of movements necessary, it should be remarked that the numerous movements which take place at the entrance of a dead end station render it essential that there should be a sufficient number of running lines in proportion to the number of platform lines, and that these should be suitably arranged. Besides this, the need for reducing the amount of shunting increases with the intensity of the traffic, and with the reduction in the time between trips. Also it is evident that platform lines should be sufficiently long to accommodate the longest trains, thus avoiding the necessity of dividing these and placing them on two lines, thereby causing additional shunting. This may entail, as in the St. Louis Station, the arrangement of the lines in two groups in order to gain useful space on the outside lines.

Owing to the inconvenience experienced when shunting on curves, it is advisable that lines on which much shunting has to be done should be straight.

8. *Separation of suburban and main line services.* — Suburban and main line services give rise to entirely different conditions, and each should have their own special accommodation. It is recognised that the two services and the shunting in connection with the same should be separated and specialised to a degree depending upon their relative importance. In stations where the suburban service is not very important, or is only so at certain periods of the day, it is sufficient to allot special platforms to it during these periods. The suburban services are especially developed in England.

9. *Baggage, post and parcels services.* — As a rule, the luggage vans are loaded and unloaled at the platforms in the station building.

None of the Administrations run trains solely for conveying luggage, and very few make a practice of placing the vans in special sidings for loading and unloading. The method generally adopted is, moreover, the most convenient one for avoiding shunting operations. Attention need only be drawn to the necessity of speeding up the loading and unloading in order to free the platform lines as quickly as possible, without being obliged to move the vans, or to draw them out to make room for another train, and then to bring them back to the platform to complete the unloading.

The same does not apply to the postal and parcels services conveyed by passenger train. As a rule the nature of these traffics renders necessary the use of separate and specialised accommodation. This will obviously cause a greater amount of shunting, but is imposed by other more important considerations. It is therefore necessary to make a careful study of these special arrangements, in order to obtain the maximum rapidity with the minimum amount of shunting, to place the vans for loading and unloading and to convey these to the trains and incorporate them therewith.

The sidings used for these services should therefore be placed close to the platform lines, as a prolongation or at the side of these, and be connected in such a way as to render communication between them easy and independent.

A number of railways have found it necessary, on account of the importance of the postal and parcels traffic, to run trains exclusively for these services. In these cases, the necessary accommodation has been developed to such a point as to become separate stations or buildings apart from the passenger station. However, when the parcels do not form the complete train load, they are as a rule loaded or unloaded while the train is standing at the platform, and are taken on hand trucks to the post or parcels office, without the necessity of any shunting.

In order to speed up unloading, without inconveniencing the passenger, in dead end stations where the luggage, postal and parcels vans are placed at the head of the train, some of the more recently constructed American stations are provided with intermediary platforms, used exclusively for parcels and other supplementary services. Experience has proved that these are very advantageous, and do not occupy an excessive amount of space.

This question of shunting entailed by luggage, postal and parcels services, should be considered in accordance with the position which the vans used for these will occupy on the train.

As we have already stated, the American railways always place these vans at the head of the train, immediately after the locomotive, hence the necessity for having, as a rule, a special lay-out for turning the trains or sets of coaches at stations where the direction of running is reversed. On other railways they are placed at the head, in the middle or at the tail, according to the local conditions of the stations, etc., with the object of facilitating marshalling and shunting in general. Some railways run luggage vans at the two ends. This arrangement is to be recommended for trains which are to run in either direction.

10. *Separate platform lines for arrivals and departures.* — It has been found that the complete separation between arrival and departure platforms in terminal stations, while being very convenient for the public and for the organization of the various services, entails great inconvenience as regards moving the train sets, and reduces the total capacity of the station. In loop stations, which have the arrival and departure platforms on the opposite side of the loop, the separation is a straight forward matter. As a rule, it is preferable to use the platform lines for either purpose, though at the same time attempting to allot to each some definite service according to the situation of the platform lines in relation to the main running lines.

11. *Movements of engines between the station and shed.* — The movements of engines between the station and the shed should be made, as far as possible, on lines independent of the main lines, and which are in communication with the platform lines and carriage sidings. It will also make for simplicity and rapidity if the engine sheds and carriage sidings are situated near to the station.

The movements of train engines present no difficulties as a rule in through stations or loop stations, or even in dead end stations where the trains set back into the station after having been turned. Waiting bays at the ends of the platforms facilitate the changing of engines of trains that are continuing their journey.

On the other hand, serious difficulties are experienced in dead end stations in liberating engines of arriving trains from the ends of the platform lines, either to allow them to return to the shed or run round the train (especially in the case of quick suburban services) when the train is taken out again by the same engine.

Lay-outs designed to overcome these difficulties are arranged to connect two or more platform lines together at the head of the platforms by simple means, such as « scissors » cross overs and traversers, or consist of central liberating lines between two platform lines, connected with these at the two extremities, or, less frequently, by turntables or traversers. These central lines are preferable for suburban services, and may at the same time be used for accommodating engines and vehicles. As a rule, however, these devices have the disadvantage of depriving the public of the most convenient part of the platform accommodation and prevent any extension of the platforms.

In the large modern dead end stations, where there is no dense suburban traffic to be dealt with, there is a tendency to simply terminate the platform lines at the buffer stops without any special devices, provided that the arrangement of the empty stock sidings allows the empty trains to be removed as soon as the detraining and unloading is finished.

In order to reduce as far as possible the movement of engines at the engine sheds, it is essential that these should be so arranged that the various operations may follow one another in their proper order, without unnecessary movement in carrying them out. In the most modern examples, engines may obtain coal, water and sand simultaneously. It is necessary to have separate lines for entering and leaving.

12. *Movements necessary for attaching and detaching vehicles.* — In order to reduce these movements as far as possible in terminal stations, interior and intermediary connections are provided between adjacent platform lines in order that vehicles may be taken out or added without having to shunt the whole train (St. Louis and Washington Stations).

For the same reasons, electric traversers are in almost general use. These link up all the lines near their ends close to the neck of the station. The use of turntables at the ends of the lines is becoming more and more rare. A turntable located in the vicinity of the station may, however, be very useful for turning engines and wagons.

We have already mentioned special central lines and also exterior lines alongside the platform lines, and waiting sidings at the ends of the platforms.

13. *Location and arrangement of empty stock sidings.* — The arrangement and location of the sidings for storing empty stock and for various operations in connection with the same are of special importance as regards the extent and facility of shunting. These sidings have a considerable influence on the general working of the station. To avoid unnecessary movements, it is necessary that these sidings should be accessible from both ends. The movement of a set of vehicles can thus be effected by simply drawing ahead or setting back without any complication.

As a general rule, in through stations or loop stations, working under their best conditions, the empty stock is drawn to the sidings by the train engine itself. It is equally rapid and easy to set back by means of the train engine. The ideal

location for the empty stock sidings is in the passenger station itself, or in its close proximity; it may, however, have to be placed some way off owing to lack of space. In the former case, it is obiously preferable to place these sidings between the main lines. They may be suitably placed alongside the arrival lines on one side or the other of the main lines, according to local conditions. In order to shorten and simplify the communication between the platform lines and empty stock sidings, it may be advisable to separate the former into groups, allotting to each group its own sidings. The empty stock sidings should be of sufficient length to avoid the additional shunting caused by having to divide the sets of vehicles. It is also desirable to provide, when possible, all the tracks with drains, and to lay on a supply of compressed air, water and steam, so as to avoid the necessity of any movements.

It is essential that the empty stock sidings should, as far as possible, be connected to the platform lines in such a way that the empty trains do not foul the main lines while being removed. It is also necessary that each of the sidings should have direct access to the platform line which it serves.

14. *Additional sidings and lines.* — It is advisable to provide additional sidings close to the neck of the station, with a shunting line in free communication with the different platform lines or storage sidings, or with those used for repairs. These sidings will serve for the temporary storage of vehicles or sets of vehicles waiting to be used, for storing special vehicles and for making up trains. These sidings are specially useful for avoiding complicated shunting operations at periods when the station is working at its full capacity.

Finally, circulating lines alongside the main lines and giving direct communication between the engine sheds, sidings for storing and cleaning coaches, accommodation for luggage, postal and parcel services, and a certain number of platform lines, are of great assistance in overcoming congestion in the busy hours of the day.

15. *Location of engine sheds.* — From the point of view of reducing the movements of light engines, it is advisable to place the sheds, and also the accommodation for effecting light repairs to rolling stock as near as possible to the station, in close proximity to the main lines, and in direct communication with the platform lines and empty stock sidings.

As a rule, a central engine shed serves for a number of stations.

We find that some stations which are served by a shed some distance off, are provided with special locomotive sidings where the engines can obtain coal and water and be turned.

16. *Connections between the various lines.* — It is essential, despite the cost, to have a sufficient number of well arranged cross-overs, turn-outs, etc., in order to reduce the shunting movements, and to render them independent of one another.

There is a general tendency to use cross-overs at the entrance of the stations, these giving communication between any pair of lines.

17. *Marshalling of trains.* — This point has already been touched upon in connection with the luggage, postal and parcels services. Careful consideration of the marshalling of trains may have a great effect towards simplifying and reducing the amount of shunting. It should be attempted as far as possible to keep the train sets in their proper order, without any alteration, thus, vehicles such as brake vans, special stock, service vehicles, etc., which may have to be attached, should be marshalled in accordance with the lay-out of the stations, so as to need a minimum amount of shunting.

18. *Carriage cleaning, heating and various other operations.* — It is obviously necessary, from the point of view of minimising movements, that operations such as cleaning, heating previous to being used, light repairs, loading up with supplies, filling with water and gas, charging electric accumulators, etc., should be carried out in the carriage sidings, without moving the coaches.

19. *Electric traction.* — Electric traction has many advantages as regards reducing the movements of locomotives and empty stock, because the electric locomotives and also the electric cars can run equally well in either direction without the necessity of turning. Also, especially in the case of suburban services, trains of permanent composition may be formed which can run, without any alteration, in either direction, using an electric locomotive or auto-car at each end, or better still, on the multiple unit system, which consists of a number of auto-cars forming a train which can run equally well in either direction, being driven from either end.

Electric trains can also arrive at one platform in a station and be despatched again from the same without any shunting. They can also be heavier and this may also allow the number of trains to be reduced. All this tends to diminish the number of movements and also obviates the need for accommodation for obtaining coal and water and for cleaning the fires.

20. *Stations on two levels.* — The lay-out of lines on two levels is rare, but has the advantage that in dead end stations special devices may be employed below ground level so as to avoid the disadvantages of the dead ends, without causing inconvenience to passengers.

21. *Various remarks.* — It should be stated that the use of the train engines for at once removing empty trains from platform lines is preferable, in order to lessen the work of the shunting engines.

Finally, it is obviously of the greatest importance that the various features of a terminal station should be so arranged, as has already been explained, as regards engine sheds, in the order in which they are used, so that operations may follow in their proper sequence with the minimum amount of movement and without unnecessary shunting.

Conclusions.

1. — Economy in working and an increase in the capacity of the stations to handle traffic justifies considerable outlay to provide equipment and methods of working which will allow the number of movements of engines and empty stock to be reduced.

It is advisable in this respect to prepare a careful estimate of the working expenses for proposed schemes and to keep statistics of existing facilities.

2. — Loop stations constitute the best method of reducing to a minimum the movements necessary for quickly liberating the platform lines, turning the trains and taking them to the empty stock sidings, and for obviating all the inconvenient shunting which has as a rule to be performed in terminal stations.

3. — A triangle, placed for preference between the station and the empty stock sidings, effects a considerable reduction in the shunting necessary to turn the trains at terminal stations.

4. — A well planned lay-out at the neck of the station is essential to the economical working and efficient utilisation of the platform lines, especially in dead end stations.

5. — It is very advantageous to separate, as far as possible, the main line service from the suburban service.

6. — The separation of the accommoda-

tion used for postal and parcels services causes a greater amount of shunting, but has advantages from other points of view.

Loading platforms for independent luggage, as well as mechanical means for accelerating the loading, unloading and handling of luggage, post bags and parcels, may effect, among other advantages, a diminution in shunting.

7. — Platform lines used for general purposes (*i. e.*, arrivals and departures) as a rule, are better than specialised platform lines, in that they allow a certain reduction in the amount of shunting and also can be more efficiently utilised.

8. — In order to liberate the engines of incoming trains from the ends of the platform lines in dead end stations, it is desirable, especially for suburban traffic, to have the platform lines in pairs connected with a liberating line placed between them, but in the ordinary case of trains which have completed their run, it is possible to economise space and to reduce the amount of shunting, while still retaining the dead ends, if the empty stock sidings are of sufficient capacity and suitably located, so as to be able to dispose quickly of the empty trains.

9. — Sidings at the ends of the platforms are very useful to allow engines to be changed quickly. They may also be used for accommodating vehicles detached from the trains at the platform, or those which are to be attached.

The general use of traversers and the use of connections between adjacent lines is of great utility in facilitating the attachment or detachment of vehicles with the minimum amount of shunting.

10. — The empty stock sidings should consist of a sufficient number of lines to be able to fully cope with the maximum amount of traffic, and should be of sufficient length to hold the longest trains without having to divide these.

They should be placed, whenever possible, within the station, preferably between the main lines, and so arranged as to be accessible from either end in order that empty stock can be simply drawn or set back into the sidings without affecting the marshalling of the trains. When the sidings are separate from the station, they should always be connected to it by independent lines so as to avoid congesting the main lines.

11. — Auxiliary sidings close to the neck of the station, in easy communication with the platform lines and empty stock sidings, are very useful for making up trains and as lie-by accommodation.

12. — Circulating lines alongside the lines in the neck of the station, and affording direct communication between the engine shed, the empty stock and carriage cleaning sidings, and from the luggage, postal and parcels warehouses to a certain number of the platforms, are of great assistance in preventing congestion during busy hours of the day.

13. — It is an advantage to place the locomotive sheds as close as possible to the passenger station, and to connect these by independent lines to the platform lines and the empty stock sidings. When the central engine shed is at some distance from the station, special facilities in the station to accommodate engines waiting there, and to coal, water and turn the same, are very convenient, and reduce the distance run by light engines, especially in the case of the shunting engines.

14. — Ample communication between the various lines assist in reducing and simplifying the shunting. The principal cross-overs at the head of the station, giving communication between all the lines, are particularly useful.

15. — It is advantageous to arrange the marshalling of the trains in such a way that as little alteration as possible is necessary at stations where the direction

of running is reversed. It is advisable in such cases to place one brake van at the head and another at the tail of the train.

16. — It is advisable to use the empty stock sidings for cleaning purposes without moving the empty stock train sets.

17. — Electric traction offers great advantages over steam traction on account of the suitability of electric locomotives for running equally well in either direction, and especially in the case of suburban services, as sets of vehicles can be run in either direction without altering the marshalling of the various units by using a tractor at either end, or better still, by means of the multiple unit system.

18. — Stations having lines at two levels lend themselves to the use of special devices for liberating engines, etc., from dead end platform lines.

19. — The movement of engines may be reduced by using the train engines for putting away the empty stock without employing shunting engines for this purpose.

20. — It is of the greatest importance that the various components of a terminal station, including the engine sheds, should be arranged in the order in in which they are utilised, so that the various operations follow in proper sequence with a minimum amount of shunting.

[621 .33]

REPORT No. 7

(Belgium)

ON THE QUESTION OF ELECTRIC TRACTION (SUBJECT VIII FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION) (1) AND BRIEF EXTRACTS FROM THE REPORTS FOR OTHER COUNTRIES,

By ERNEST GERARD,

ENGINEER,

HONORARY GENERAL SECRETARY OF THE MINISTRY FOR RAILWAYS,
MARINE AND POSTS AND TELEGRAPHS OF BELGIUM,

PRESIDENT OF THE BELGIAN COMMITTEE FOR SAFETY IN DISTRIBUTION OF ELECTRIC CURRENT.

A. — General

As far as results of experience are concerned that might be of assistance in throwing light on certain technical problems connected with the electrification of railways, the Belgian State has only to its credit the trials of six accumulator rail motor vehicles put into service between the years 1892 and 1897.

These were fitted with various types of motors placed directly on the axles, *i. e.*, without gearing. The vehicles were also fitted with control apparatus and also appliances for braking and signalling.

Various firms were commissioned to construct shunt excited, straight series and compound motors, all working with continuous current of 600 volts. Fitted with accumulators, the weight of which was equivalent to a hauled vehicle, the rail motor cars ran on different sections of the system with varying gradients (2).

We will return later on to the technical and economical results of this experiment dealing with the comparison of different types of motors.

At this stage, however, we will consider as the important points of electrification, the transmission between source of supply and contact wire; the type and pressure of the current; the method of collection on the vehicle; the type and construction of motors; and the method of transmitting power to driving wheels.

Admitting in this respect, that Belgium has no history, we may be tempted to add, according to the well known dictum that in this she may be considered fortunate. Have we not for instance seen the wholesale abandonment by the French Com-

(1) This question runs as follows : « Electric traction on lines with much traffic : production and transmission of energy ; type of current ; locomotives, motor cars. Technical and financial results obtained. Comparison with the results of steam traction ».

(2) See *Bulletin du Congrès des chemins de fer*, t. 9, 1895-2, p. 2211, and *Bulletin of the International Railway Congress*, t. 19, 1905, p. 999 and following ».

mission of all the systems that had been set up in that country as described in Mr. Sabouret's report? Have not England and Holland also adopted a similar attitude towards the greater portion of the partial electrifications that had been carried out on their railways?

Would it not therefore be preferable to have been amongst those who have held back? To this our answer is, No. Those who doubt the wisdom of such a reply should not forget that in a complex subject such as this where there are involved the technics alike of the production of electricity and of its utilisation for traction purposes, there is no substitute for experience gained by actual practical investigation, even the difficulties incurred and overcome being in this respect advantageous [1].

It is the countries that have had actual experience, especially in the last decade, who will be in a position to bring reliable information to the Congress; to substantiate theories hitherto academic only, and to put forward as successful solutions of problems that have been encountered, methods some of which have already been definitely adopted on certain railways.

In order to present a summary of the work carried out with a statement of the considerations which have influenced these decisions, we have been asked to present to the Congress a résumé of the work of the reporters, and to follow as far as possible the order in the text of question VIII.

« Generation and transmission of pow-
« er; nature of the current, locomotives,
« rail motor cars. Technical and finan-
« cial results obtained. Comparison
« with results obtained from steam trac-
« tion. »

(1) Have we not in Belgium learnt valuable lessons from our trials of the accumulator operated rail motor cars, especially with the gearless motors, their methods of suspension, the driving of the wheels, the control apparatus, the calculation of the tractive resistance of the rail motor cars with or without a load, etc. (See the article in the 1905 *Bulletin* already referred to.)

B. — Generation and transmission of power.

Italy. — From the experience of the Valtellina lines which were equipped in 1901-1904 with 3-phase current, it is evident that the lines of Northern Italy could be electrified with this type of current obtained from hydro-electric stations making use of the energy of water falls and alpine torrents, the current being used on the railway either at the pressure at which it is generated or after transformation to a lower pressure without any further conversion or change of periodicity.

If regard be had to the history of the application of electric traction to railways it will be easily seen that the lessons taught by this trial installation are on the one hand that the system should be extended to other mountain lines and on the other hand that it is possible to utilise directly on the trains current in the form in which it has been primarily generated, *viz.*, 3-phase current at low frequency. In such cases where they have not been specially erected for railway purposes, the Italian Hydraulic Power Stations have been arranged so that they produce simultaneously both low frequency current at 15 to 17 periods for railway purposes, and higher frequency current of 42 to 50 periods for general power and lighting purposes, thus enabling the stame station to serve the different requirements, and, by obtaining the maximum economy to further the scheme for substituting electricity for steam on the Italian State Railways.

Switzerland. — It is in this country

that the connection between the current as generated and its utilisation for railway electrification is most marked. Attracted by the simplicity of the single overhead conductor required by the H. T. single-phase system which had been experimented with on the Seebach-Wettingen Line by the Oerlikon Works Company since 1903, the Federal Authorities, in common with many engineers in all countries, saw therein an attractive solution of the long standing problem of economical transmission to the working conductor of the railway.

Without doubt the progress made in the design of series-compensated single-phase motors had some influence, but as these motors were only capable of using low tension current and as consequently a transformer had to be carried on the vehicle in any case, the limit to the working pressure on the contact wire could be indefinitely high excepting in so far as it was limited by considerations of practicable insulation. To use the current at such pressures on the actual vehicles and without any conversion was to realise an ideal hitherto striven after by railway engineers everywhere.

It was easier to utilise such a method of traction in Switzerland since the waterfalls available are so numerous that it is only necessary to utilise a few of them for the railway supplies; thus what Mr. Hüber's report outlines to us is a high capacity system of transmission mains fed by combination of hydro-electric stations having large reserves of water in natural or artificial lakes and supplying single-phase current at a pressure of 15 000 volts, at a periodicity of 16-2/3rds, this current being fed directly to the contact wire and the vehicles; the power stations are inter-connected and so divide the load suitably between themselves. This is the most unique local position of happy Helvetia, which as a result ceases to be dependent upon the foreigner for the supply of fuel at its terribly high price.

Scandinavian countries. — The position with respect to « white coal », as water power is sometimes called, is similar in Sweden and Norway to that of Switzerland. These countries being of much greater area naturally have their railway systems more spread out, consequently the distances over which current has to be carried necessitate its being transmitted at a pressure too high to be used directly in the contact wire. At most, however, when the output of certain hydro-electric stations is specially set apart for the supply of electrified railways, the system to be used would be a single-phase system, (the use of which was decided upon after the trials of 1910), and it will only be necessary to transform the current transmitted at very high pressures down to 16 000 volts.

France. — The result of enquiries made by various committees appointed by the French Government ended in the issue of regulations having for their object the combining of the sources of power for general public consumption and for those required by railways for the future electrification of 8 000 km. (5 000 miles) of lines during a period of twenty years, the primary current being uniformly three-phase of 50 periods. It will therefore be converted to the use of electric traction under whatever form the latter may require it.

England. — An act entitled « Electricity Supply Act » which especially aims at *economy in the generation of current* places electrification under very wise regulations. Mr. van Loenen Martinet clearly explains the economical value of

this act. The following are the essential points as regards the electrification of railways. The country is sub-divided into thirteen electric districts under the supervision of the Board of Trade Commissioners. In its application the Act allows of certain temporary compromises which take into account the relative situation of this industry in the district. As regards big enterprises such as the electrification of railways, the companies cannot obtain a license to supply electric power themselves unless they can prove that they *are able to produce the current at a lower rate than they can buy it from a power supply in the district for which it is required.*

The commissioners show a leaning towards standardisation of the main supply as under the form of three-phase current of 50 periods.

Holland. — A commission having estimated the general yearly requirements of the country at 1 000 million kw.-h., and in addition 400 million kw.-h. for the railways, has considered it advisable to combine the sources of power for this double object. Although the principal electrified railway, *viz.*, that of the Rotterdam to The Hague-Scheveningen is equipped with single-phase current, the official Commission has ignored this and has decided against the principle of taking alternating current for reasons which will be given in the paragraph relating to the nature of the chosen current. The generation of power will be centralised in large stations, from which the output common to all the requirements of the country will be regulated by means of distribution of the load to the sub-stations. The type of primary current will be three-phase at 50 periods, already adopted for numerous undertakings.

Belgium. — Up to the present time there has been no law in Belgium to regulate the generation or distribution of electric power from the commercial point of view.

Only the question of public safety has led the Government to make regulations based on authority given through the Commission, which for a long time has dealt with roads, railways, telegraphs and telephones.

The communes, who are very jealous of their autonomy, have always endeavoured to prevent any legislative action. Fortunately the great companies for the production of electricity have had the foresight to anticipate the industrial future of the country as well as the business of the railways : the current generated is generally three-phase at 50 periods.

Owing to the Commission, however, having decided not to allow the use of alternating currents in the contact wire the three-phase current must be converted for electrification purposes.

America. — In Mr. Gibbs' report no mention is made of any intention on the part of the American authorities to issue any rules for the generation of electrical power which would affect the technical considerations of electrification. It is quite evident that such rules could hardly be put forward by the central authority when the very different natural characteristics of the various regions of the Republic are taken into consideration. Also in each of the States of the Union private industry has shown so much initiative in this respect that most railway companies who have partly or wholly electrified their systems prefer to purchase current than produce it, even when they make use of enormous quantities.

C. — Type of current. Locomotives. Motor vehicles. Technical results.

General. — The nature of the current that is to be collected along the road, the motors and the apparatus for regulating the running, are all inter-related; also the speed and weight of the trains are related to the tractive effort available for the gradients of the line.

Consideration of these elements alone does not, however, decide the type of current to be carried by the contact line. The power current running through the latter, the motors, the return conductor (rails or earth), may induce currents in telegraph and telephone circuits, or cause destructive electrolytic action on underground metallic piping.

We shall see that the fear of these disturbing influences occasionally overweighs the decisions relative to the kind of current that it may be desirable to adopt.

Those who are experienced in these matters will appreciate that the systems which have been tried on metropolitan intersuburban lines or suburban sections of the large railways, which employ continuous current at 600 to 750 volts, will be confined to these purposes on account of the great expense entailed in the transmission of power at these low pressures.

According to the reports submitted for the Congress at Rome, it seems to be also admitted that the actual state of practical experience with high pressures, limits the choice for the present to three types of current for the practical use of railway engineers :

Three-phase with a pressure of at least 3 000 volts;

Single-phase with pressure from 10 000 to 16 000 volts;

Continuous current at 1 500, 2 400 or 3 000 volts.

The installations of each of the first two systems vary according to the country in which they have been adopted or applied on a large scale.

The respective features may be summarised as follows :

Three-phase. — From the low pressure of 500 and 750 volts 40 periods tried in Switzerland on the Lugano Tramway in 1895, then on the railway from Burgdorf to Thun, the Italian Engineers went up at once to 3 000 volts on the Valtellina lines (106 km. = 66 miles) the equipment for which was commenced in 1901, making use of the primary current from the special central hydro-electric station at Morbegno, directly generated with 15 periods at 4 000 volts falling to 3 000 by losses in the cables to the contact wires.

To the administration of the Italian State Railways therefore belongs the credit that in 1901 they made the first use of a relatively high pressure in the electrification of railways.

This pressure moreover has only been exceeded in three-phase working in two small installations, *viz.*, the 10 000 volt trials of motor vehicles for extra high speed on the 23 km. (14 1/2 miles) line from Marienfeld to Zossen; and the use of 6000 volts on the 10 km. (6 1/4 miles) line in the United States, part of which is in a tunnel.

The success of this pioneer work and the experience gained induced the Italian Government to adopt three-phase 3 000 volts, 16-2/3rds periods, for lines of heavy gradients, crossing, by means of tunnels, mountain chains in districts where current generated from water power was available. Abolishing thus the inconvenience of steam in tunnels it was also found that the three-phase system ensured speed being automatically maintained throughout the journey, and enabled

braking to be accomplished by regeneration of power which in its turn resulted in reducing rail, tyre, and brake-block, wear.

Amongst the 675 km. (419 miles) of railway, or 1 300 km. (807 miles) of track electrified in Italy in 1921, it is the 290 km.(181 miles) equipped with three-phase at 3 000 volts 16-2/3rds periods which call for special attention.

The contact wires are composed of two overhead conductors, a third being formed by the rails suitably bonded together. Instead of being supported longitudinally by a catenary cable, the overhead wires are carried transversely by means of brackets on the posts which are fixed 35 m. (145 feet) from each other; a metallic connecting piece is hung from the bracket carrying through its insulators a sheathed insulating wire on which are the two insulators to which the contact wires are respectively attached. Their insulation is tested to 30 000 volts and the current is picked up by means of a double bow :

« This double wire, as the reporter in-
« forms us, gives a complicated appear-
« ance, but it will be seen, however, that
« the complication is more apparent than
« real. »

Then further on :

« The longitudinal type of suspension
« (by means of a catenary wire which
« had been tried on the Valtellina) has
« not been adopted generally for econo-
« mic reasons and because it is unneces-
« sarily complicated. »

« The type of transverse suspension
« costs less and is much simpler to erect
« and inspect, thus permitting the fitting
« up of the line to be carried out more
« quickly and subsequent repairs more
« rapidly and easily, whilst upkeep is
« less costly. »

The report confirms these claims with rather convincing figures, especially those relating to the suspension of the double wires for ten lines of rail from a double bracket on a single pole.

Finally as regard bonding the rails, the reporter considers that the application of an anti-rusting paste applied between the rails and the fishplates, which have been previously thoroughly cleaned with a sand blast and metallic brush, is both simple and efficacious.

Electric locomotives. — Independently of locomotive trials on the Valtellina railways, tests were also made with the self propelled *Gearless* vehicles fitted with a rotor fixed on a quill; the drive to the wheels was effected by means of an ingenious arrangement of rods and cranks jointed to the spokes of the wheels. Their adoption, however, has not been extended to other lines that have since been equipped with three-phase current.

The locomotives of 2 000 and 2 600 H. P. are all worked through the medium of coupling rods.

The drawbar pull does not exceed 10 tons nor the weight per axle 15 tons, limits fixed by the Italian State regulations.

The reporter supposes that we are familiar with the different arrangements of transmitting mechanical power to the driving wheels by means of coupling rods, etc. A well known form of drive is that of coupling two motors supported on the framework of the vehicles by means of a triangular rod or yoke-piece (known in Great Britain as a Scotch-yoke). At the lower apex of this triangle there is cut a slot in which works the crank pin of the central driving wheel; the other driving wheels are in their turn driven through the medium of rods from two eyelets one on each side of the slot.

On other engines the cranks, keyed on to the shaft of the motor, work by means of obliquely fixed coupling rods the cranks of a jack-shaft from which power is transmitted by means of coupling rods (1).

The weight of the most numerous classes of locomotives is as follows :

TYPE.	Power in H. P.	Speed in km. per hour at 1 hr. rating.	Total weight in tons.	Weight per H. P., in kgr.
E. 505 with 5 driving wheels	2 000	22.5 — 45	60	30
E. 330 with 3 driving wheels	2 600	37.5 — 50 — 75	73	28

The figures relating to the consumption of electric energy given by Mr. A. Donati are relatively small, and we will reproduce them. They refer to a section, Pontedecimo-Busalla, part of which has an incline of 1 in 28.6 run over at a speed of 45 km. (28 miles) per hour with probably a full load, the power measured at the bows collecting the current being as follows :

Per virtual ton-kilometre (1) up the incline, 19 w.-h.;

Per virtual ton-kilometre up and down, 9 w.-h.

It will be seen that by regeneration it is possible to economise current very materially.

The mean yearly consumption for the supply of this section taken at the central station situated 15 km. (9 miles) away was 24 w.-h. per virtual ton-kilometre.

With these figures, which relate to haulage by three-phase current, Mr. Donati compares the actual consumption of the motor vehicles running on the Milan-Varese line, this being 46 w.-h. per virtual ton-kilometre measured at the central station 20 km. (12.4 miles) away. Mr. Donati considers that the weight of the three-phase locomotives is less than that of locomotives using continuous current, basing his remarks on an investigation made with a view to the equipment of the Benevento-Foggia section with continuous high tension current when it was found that it would be necessary to strengthen the bridges, etc., on the line. We shall see later on what this amounts to in making a general comparison between electric locomotives.

The power lost in the rheostats through the starting of three-phase locomotives varies from 1 to 1.7 % of the total.

Transmission of power by means of coupling rods, especially through the intermediary of the Scotch yoke is in every way satisfactory. As regards lubrication, upkeep and repairs, the comparison is very similar to that of steam locomotives.

Substations are relatively numerous, being only 16 km. (10 miles) apart on certain sections. The power required, however, on steep gradients by heavy trains must be taken into consideration. Without doubt, as Mr. Donati says, increasing the pressure would allow the substations to be fixed further apart, and it would be possible to raise it to 5 200 or 5 400 volts without having to alter the insulation of the apparatus on the lines.

(1) As regards these locomotives, complete details are given concerning the mechanical and electrical apparatus in the recent work by Professor Tajani : *Tratto moderno di Materiale Mobile ed Esercio delle Ferrovie*, P. Tajani, Prof. Politecnico de Milano, 1921.

(1) This term implies the moving of one ton for one kilometre on a line which is perfectly level and straight.

A higher pressure in the contact line, such as one in the neighbourhood of 10 000 volts for instance, would have to be reduced on the locomotive and would do away with the simplicity of the three-phase arrangement. It would also cause a certain amount of inconvenience in tunnels, as was experienced, it is said, in the Loetschberg, by the ionisation of the air which thus loses its insulating properties.

The reporter concludes that in Italy the three-phase system fulfils all the technical and economical requirements that were expected from it in working the mountain lines to which it is applied, and that there is no adequate reason for adopting any other in this part of the country. The authorities, however, will examine without bias the advantages that may be offered by other systems for less hilly regions of the peninsula.

Single-phase. — The official adoption by the Swiss authorities of single-phase current of 15 000 volts 16-2/3[rds] periods, as much on account of the economy realised in the delivery of the current into the contact wire as for the simplicity of the overhead apparatus, its supports and that of the collecting apparatus, and also the fact that 510 km. (320 miles) of lines are already in satisfactory operation, naturally influences the reporter for Switzerland to advocate this system.

As we have already seen in the paragraph above dealing with the production of electric energy in this country, this is delivered direct in the form of single-phase current at 16-2/3[rds] periods, the original pressure being simply regulated so that the potential at the feeding point on the working line drops to 15 000 volts. Along the line runs a cable, generally of aluminium, suspended by insulators on the same posts as the catenary cable, and acting as a feeder to the contact wire to which it is connected at various points. The simple catenary suspension carried by insulators on brackets and posts fixed at 60 m. (197 feet) apart on the straight and 30 m. (98 1/2 feet) on curves is preferred.

Neglecting the Rhaetian Railways with narrow gauge and very varied gradients, we will deal with certain characteristics of other railways worked with single-phase current.

The units of electrical energy consumed are given by the reporter in gross kilometric tons.

SECTION OF LINE.	Bernese Alps.	Berne to Scherzligen.	Erstfeld-Biasca.
Maximum gradient in mm. per m.	27	10	27
W.-h. per tkm. at the pantograph collecting bow.	Mean : 51	Summer : 35	...
W.-h. per tkm. at the Central Station.	...	...	48

It is unfortunate that the consumption is not given in virtual kilometric tons. In addition, the reporter remarks that these figures were taken at a period when regeneration had not yet been made use of. This improvement recently tried with success in Switzerland on locomotives fitted with single-phase motors, saves the latter from one of the objections brought against them when compared with those of other systems.

As regards the injurious effects of single-phase circuits on those of telephones and telegraphs, we must agree with the reporter that in mountainous countries, and especially in tunnels any expense arising from the means taken to obviate this inconvenience is naturally of

relatively small importance because there is always danger in respect to any overhead transmission lines of telegraph and telephone wires falling across the high pressure conductors, while again such lines have no claim for the space at the side of the railway to be, nor in the circumstances can such space be reserved for them, so that their removal from the vicinity of the single-phase disturbance is necessary in any case. With regard to the more or less complicated methods that have been tried in Switzerland with a view to preventing induction, the reporter expresses the view that the best remedy is that of cabling the telegraph and telephone wires, the cable being lead covered and armoured with the armour and lead covering electrically connected together, and earthed.

Moreover, from the point of view of the nature of the current, feeding the contact wire direct at the original pressure from the hydro-electric central stations was possible in Switzerland, and under conditions which justified the case of a high tension alternating current. As the single-phase system has in addition to economy in transmission the advantage of a single contact wire, these points have overweighed the consideration of the weight of the motors, and a slight excess in consumption of current. As far as we are concerned, the principal question is to know if the technical working of the system is quite satisfactory, and this is answered in the affirmative.

High tension continuous current. — According to the reports of Messrs. Sabouret and van Loenen Martinet, France, Great Britain, and Holland have definitely adopted continuous current at 1 500 volts for the future electrification of railways in general use [1].

Though certain technical results obtained in England on the Manchester-Bury line, fitted with a third rail at 1 200 volts, and the Shildon-Newport line, also worked with continuous current at 1 500 volts and overhead conductor, had influenced the opinion of railway engineers in this respect, it appears to have been more especially confirmed by the brilliant results realised in the United States, especially on the Rocky Mountains lines where pressure as high as 3 000 volts is used.

The reasons for arriving at this decision were chiefly the following :

A. — In England, as in France and Holland, the telegraphic and telephonic communications are carried out by means of important overhead groups of wires running along the sides of the railways. Any powerful alternating current would in these circumstances create an induction in the wires against which there is no remedy, unless they were removed to other positions or placed in cables.

The resulting expense would saddle the first costs of electrification with prohibitive charges; it would be necessary to maintain during the alterations the pre-existing means of telegraphing and telephoning, so that any change would be almost entirely an additional expense.

B. — The continuous current motor can be constructed for 750, 1 200, and 1 500 volts without losing any of its inherent advantages, such as relatively moderate weight, wide range of speed, and regeneration on falling gradients, giving a retarding action without the use of other brakes.

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[1] Pressures of 1 200 to 1 500 volts in contact lines have long been in use on local public railways, especially since the motor with auxiliary commutation poles has made it possible to raise the power and the pressure which were formerly limited.

C. — Multitraction [1] may gain in security by the fact that the trolley wire, although having a very strong continuous current, may transmit at the same time a weak alternating current for the inter-control of the motors.

D. — The limitation to 1 500 volts rather than to 2 400 or 3 000 is based on the actual situation of the railways in those three European countries where they form compact systems, and will never have to be fed from any great distance from the sources of supply of electric energy, it is therefore preferable to fix on a rate of pressure which makes it easier to insulate the overhead gear and that of the control and of the motors.

E. — Finally it is considered that the 1 500 volts current may be delivered without taking excessive precautions, as easily to a third rail as to an overhead wire. The third rail system at 1 200 volts is already working successfully on the Manchester-Bury section, and according to competent engineers on the Lancashire & Yorkshire Railway, the pressure could be raised with very little alteration to existing arrangements.

We may point out in passing that all these considerations are perfectly applicable to the railway system of the Belgian State on account of the groups of telegraph and telephone wires and their position on the railways, also from the point of view of feeding the latter with electricity, and the relatively little distance between the existing or projected central stations.

The reporter for the United States, Mr. George Gibbs, does not share the optimism of his European colleagues in favour of high tension continuous current; he says :

« It is not yet apparent that the high « voltage direct current system, which is « similar in many of its features to the « system of continuous current at low « pressure transmitted along the railroads by the third rail, possesses the « elements of flexibility and adaptability « required for all kinds of railway service to the degree that these are present « in the high tension alternating current « system. »

Later on we will return to the investigations by Mr. Gibbs, but will mention here is objection to one of the arguments given above in favour of high tension continuous current; this relates to its value of allowing of the choice between the overhead wire and the third rail with currents up to 1 500 volts. In his opinion even if the classical 600 volts with third rail has sufficed for suburban lines, and for termini congested with the movements of steam locomotives, a system at 1 500 volts would be economically inefficient for the electrification of the long lines in the United States. It would, he holds, be necessary to increase the pressure to 2 400 or 3 000 volts, which would prevent the possibility of using the third rail as it would be impossible to use it with this voltage on sections on which there are many level crossings.

GENERAL COMPARISON OF MOTORS. — Amongst the points which must be considered in connection with the systems dealt with are the technical features of the locomotives and motor vehicles.

Electric locomotives. — For the convenience of the reader we have gathered together, with some little difficulty, the

[1] « Multitraction ». — This expression is used throughout this paper when referring to the working of trains by means of two or more locomotives, *i. e.*, one in front and the other at the rear, or with an additional locomotive in the middle of the train.

somewhat meagre details capable of comparison with regard to this subject from a mass of information which was somewhat lacking in some reports and quite copious in others. It is with some truth that most of the reporters point out that there is no standard method of setting out details of results so that a proper comparison may be made of the various systems.

Three-phase locomotives. — Particulars.

Italian types : 3 000 to 3 300 volts, 16.7 periods.

Type	...	E. 550	E. 330
Total weight. — P.	kgr.	60 100	73 000
Adhesive weight. — A	kgr.	60 100	48 000
Number of motors	...	...	...
Power of the locomotive at 1 hour rating	H. P.	2 000	2 600
Tractive effort at 1 hour rating.	F. H.	12 000 [1]	9 000 for volts from 37 to 50
		...	9 500 — — 50 to 75
		...	6 000 — — 75 to 100
Normal speeds	V.	22.5 to 25	...
		45 to 50	...

[1] This is a correct translation, but does not convey anything to us from an electrical standpoint as far as English practice is concerned. (*English Editor.*)

Single-phase locomotives. — Particulars.

— —	Locomotives of the Lötschberg line. Transmission by gearing and coupling rods.			Locomotives of the Swiss Federal Railways. Transmission by gearing and coupling rods.					
				Berne-Schersligen.				Erstfeld-Biasca.	
Column number	1	2	3	4	5	6	7	8	9
Type	C-C	1-E-1	1-E E-1	1-C-1	1-B B-1	1-B B-1	1-C C-1	1-B B-1	1-C C-1
Number in service	1	13	3	1	1	1	1	26	33
Number of driving axles	6	5	4	3	4	4	6	4	6
Total weight in tons. T.	90	107	70	90.9	113.5	107.1	126.8	106.5	128
Adhesive weight. A.	90	87	50	58.5	80.4	75.6	105.0	76.8	108.6
Weight of electrical equipment. E.	40	59	35	44.1	58.3	49.8	56.2	47.2	55
Diameter of driving wheels	1.350	1.350	1.23	0.930	0.930	0.930	0.850	0.930	0.930
Number of motors	2	2	2	2	4	4	4	4	4
Voltage on the locomotives	420	520	400	425 500	440 550	550 627	480 630	510 630	400 500
Horse power at 1 hour rating	2 000	2 500	1 000	1 650	2 300	2 000	2 050	1 800	2 250
Speed in kilometres per hour rating	42	50	35	47	54	49	39	46	36
Tractive power in kilograms at 1 hour rating	...	...	...	9 600	11 500	10 800	14 250	10 500	17 000
Weight per horse power based on 1 hour rating	45	43	70	55	49.4	53.6	61.9	59	57

United States. — New York, New Haven & Hartford Railroad : 11 000 v.

AC = Single-phase. — Certain locomotives marked AC-DC can also be worked with continuous current.

Class.	Number in service.	Date.	Class of service.	Type.	Voltage of overhead wire and third rail.	Number and diameter of driving wheels. D.	Method of drive.	Weight in pounds. Total. T.	On the driving wheels: t = total. e = per driving axle. A.	Electric equipment. E.
A-1	41	1907	Passenger.	AC-DC 2-4-4-2	11 000 and 600	8 62"	Gearless quill.	220 140	*t* 169 050 *e* 42 263	112 000
A-7	34	1911	Freight.	AC 2-4-4-2	11 000		Geared quill.	219 500	*t* 165 000 *e* 41 250	98 600
A-9	5	1919	Passenger.	AC-DC 2-6-2 + 2-6-2	11 000 and 600	12 63"	Geared quill.	350 000	*t* 233 000 *e* 38 833	176 500
A-11	14	1912	S. W.	AC 0-4-4-0	11 000	8 63"	Geared quill.	159 200	*t* 159 200 *e* 39 800	75 800

Class.	Power of locomotive. Tractive effort in pounds. Forced ventilation. For one hour rating.	Continuous rating	One hour rating. H. P.	Continuous rating. H. P.	Speed in miles per hour. At one hour rating.	Maximum safe speed.	Motors. Number.	H. P. 1 hour rating (forced ventilation).	Type of current.
A-1	9 700	6 400	1 420	1 125	54.5	88	4	350	A. C.
A-7	18 200	12 400	1 700	1 350	36	54	8	170	A. C.
A-9	21 000	14 500	2 550	2 025	45.6	70	12	170	A. C.
A-11	23 200	14 800	750	572	12	25	4	188	A. C.

Continuous current : high tension.

Chicago Milwaukee & St. Paul Railroad. — Continuous high tension current : 3 000 volts ; except C^3, 1 500 volts.

Class.	Date put in service and number.	Service and type.	Driving motor wheels. Number.	Driving motor wheels. Diameter in inches.	Method of drive.	Weight in pounds. Total T.	Driving wheels. Total A.	Driving wheels. Per axle.	Electric equipment. F.
C-1	1916-17 42	Freight. 4-4-4 + 4-4-4	16	52″	Twin geared.	576 000	450 000	56 250	248 000
C-2	1916-17 4	S. W. 0-4-4-0	8	40″	Geared.	143 200	143 200	35 800	62 300
C-3	1915 1	S. W. 0-4-0 1 500 v	8	36″	Geared.	100 000	100 000	25 000	33 912
C-4	1920 5	Passenger. 6-8 + 8-6	24	44″	Direct.	521 200	457 800	38 150	234 650
C-5	1920 10	Passenger. 4-6-2 + 2-6-4	12	68″	Quill geared.	524 780	367 550	61 260	270 000

S. W. = Shunting engine.

Class.	Power of locomotive. Tractive effort in pounds. (a = Natural ventilation. h = Fully excited.) 1 hour rating F. H.	Continuous. F. C.	One hour rating. H. P.	Continuous rating. H. P.	Speed in miles per hr. One hour rating.	Maximum safe speed.	Motors. Number.	One hour rating. H. P. Forced ventilation.
C-1	*a. h.* 84 500	*h.* 70 700	3 440	3 000	15.25	35	8	430
C-2	*a. h.* 21 400	*h.* 14 000	660	480	11.15	35	4	165
C-3	12 700	...	322	...	9.5	...	4	80
C-4	*a. h.* 48 500	*h.* 42 000	3 500	3 200	27.1	90	12	290
C-5	*h.* 66 000	*h.* 49 000	4 200	3 400	23.8	65	6	700

These figures may appear ambiguous if the relation between the various factors are not taken into account.

It is not sufficient for instance to speak of the comparative weight of two types of locomotives by dividing their respective weights by their horse power. Certain conditions necessary for safety when running at high speeds may require one of the locomotives to be heavier than the other without this being in any way due to the nature of the current working it. This is the case for example when two bogies, one at the front and one at the back, add about 50 t. to the gross weight of the engine and so sensibly increase its weight per H. P., although the increase in weight may be but a small percentage of the total tonnage of the train.

It was also advisable therefore to consider the total weight in relation to the adhesive weight and that of the electrical equipment, the ratio of these weights, and their relation to the tractive effort.

The particulars taken from the foregoing tables will be designated as follows :

T = Total weight of locomotive;
A = Adhesive weight;
E = Weight of electrical equipment;
H. P. H. = Output in horse power at 1 h. rating.
F. H. = Tractive effort in kgr., at 1 h. rating.

Results of comparative figures.

Types or class.	$\frac{E}{T}$ Ratio.	$\frac{E}{A}$ Ratio.	$\frac{T}{H.P.H.}$ Kgr.	$\frac{A}{H.P.H.}$ Kgr.	$\frac{E}{H.P.H.}$ Kgr.	$\frac{T}{F.H.}$ Ratio.	$\frac{A}{F.H.}$ Ratio.	$\frac{E}{F.H.}$ Ratio.	Rated speed, in kilometres per hour.
Three-phase Italian locomotives, 3 000 to 3 600 volts, 16.7 periods.									
E-500	...	..	30	30	...	5.0	5.0	...	22.5 to 25 45 to 50
...	...	...	...	...	...	8.1	5.3	...	37 to 50
E-330	...	...	28	19	...	7.7	5.0	...	75
...	...	...	...	...	...	12.1	8.0	...	100
Single-phase locomotives.									
Switzerland. — Lötschberg, 15 000 volts.									
1-E-1	0.55	0.68	43	34	23.6	...	...	...	50
Erstfeld-Biasca (St. Gothard route).									
1-BB-1	0.44	0.61	59	43	26.2	10.14	7.3	4.5	46
1-CC-1	0.43	0.50	57	48	25	7.5	6.4	3.2	36

Results of comparative figures. (*Continued.*)

Types or class.	$\frac{E}{T}$ Ratio.	$\frac{E}{A}$ Ratio.	$\frac{T}{H.P.H.}$ Kgr.	$\frac{A}{H.P.H.}$ Kgr.	$\frac{E}{H.P.H.}$ Kgr.	$\frac{T}{F.H.}$ Ratio.	$\frac{A}{F.H.}$ Ratio.	$\frac{E}{F.H.}$ Ratio.	Rated speed, in kilometres per hour.
United States. — New York, New Haven & Hartford Railroad, 11 000 volts.									
A-1	0.51	0.66	70	54	36	22.7	17.4	11.6	87
A-7	0.45	0.60	58	43	26	12.6	9.1	5.4	58
A-9	0.50	0 76	62	41	31	16.6	11.1	8.4	73
High tension continuous current locomotives.									
England. — Schildon-Newport, North Eastern Railway, 1 500 volts.									
...	...	...	68	...	...	...	...	...	40
United States. — Chicago-Milwaukee & St. Paul Railroad, 3 000 volts.									
C-1	0.43	0.55	75	58	32	6.82	5.3	2.94	24
C-4	0.45	0.51	68	59	30	10.8	9.4	4.4	43
C-5	0.51	0 74	56	40	29	8	5.6	4.1	38

On examining these results, it will be seen how easy it is to form an erroneous idea if a comparison is made of the power based on the relation between the total weight and the horse power.

Thus, the Chicago-Milwaukee locomotive type C-1 shows up very badly with $\frac{T.}{H.P.H.} = 75$ kgr., is rather better with $\frac{E.}{H.P.H.} = 32$ kgr., and very good as regards the distribution of weight to the enormous tractive effort it exerts, and especially as a function of the weight of its electric equipment $\frac{E.}{F.H.} = 2.94$ where it is ahead of all those mentioned. As regards the adhesive weight in relation to this tractive effort $\frac{A.}{F.H.}$, it is only equalled by the Italian three-phase locomotives, amongst which that of type E. 500 runs at the same speed as the American one.

Whatever light these figures throw on the comparative merits of the locomotives, it is a pity that it cannot be completed by adding the hourly consumption of current measured at the contact wire. The few figures in the reports bearing on this point cannot be compared, because they are not brought to the same unit of comparison, *viz.*, that of the virtual ton-kilometre, a method only employed by Mr. Donati for the Italian locomotives.

Let us hope that this common unit may be adopted for all comparative investigations of this kind.

Motor vehicles. — From the reports sent in, we give the comparative details relating to motor vehicles working on the different systems.

Though supplied with three-phase current, the prototype of the motor-vehicles running on the Lugano tramway was worked with a system of gearing, those of the Valtellina railways, in advance of their predecessors, were fitted with the gearless quill drive motors with 30 mm. (1-3/16 inches) play round the axle and suspended by means of coupling rods and cranks to two of the spokes of each corresponding wheel. The reports give no further details.

We will proceed therefore to the extracts concerning the motor vehicles with single-phase and high tension continued current.

Motor vehicles with single-phase current — Particulars.

Class and date.	Type.	Weight in tons.			Driving wheels.		Motors.			H.P. per motor at 1 hour rating.	Transmission by gearing.
		Total. T.	Adhesive. A.	Electric equipment. E.	Number.	Diameter.	Number.	Gear ratio.	Voltage.		
Switzerland. — Lötschberg : Single-phase, 15 000 volts.											
3	B-2	54	30	20	4	1.10	2	$\frac{1}{3.45}$	300	450	...

Class and date.	No. in service.	Diameter of driving wheels in inches.	Weight in pounds.			Motors, all with gearing.					Seating capacity.
			Total. T.	On the driving wheels. A.	Electrical equipment. E.	Number.	Gear ratio.	Power at rated speed.			
								Tractive effort F. H.	Rated speed.	H. P. per motor.	
United States. — Single phase, 11 000 volts. New York, New Haven & Hartford Railroad.											
G-1. 1914	1	36″	156 500	156 500	44 000	4	$\frac{23}{67}$	8 800	23	150	76
G-2. 1911	1	36″	139 700	139 700	56 600	4	$\frac{23}{67}$	8 800	23	150	76
G 6. 1915	2	42″	169 000	169 000	60 000	4	$\frac{22}{58}$	...	...	...	...
G-7. 1916	2	42″	170 000	170 000	54 160	4	$\frac{23}{77}$	...	...	...	...
New York, Westchester & Boston [1].											
H-1. 1911 1917	40	42″	120 000	71 750	55 200	2	$\frac{25}{68}$	...	57	140	78

[1] On these lines trains are generally made up of all motor cars and no trailers.

Motor vehicles with single-phase current.— Particulars. (*Continued.*)

Class and date.	No. in service.	Diameter of driving wheels in inches.	Weight in pounds. Total. T.	On the driving wheels. A.	Electrical equipment. E.	Motors, all with gearing. Number.	Gear ratio.	Power at rated speed. Tractive effort. F. H.	Rated speed.	H. P. per motor.	Seating capacity.
Pennsylvania Railroad-Philadelphia (1).											
I-1. 1915	82	38″	118 600	70 600	60 000	2	$\frac{24}{55}$	3 800	44.5	225	72
I-2. 1915	9	38″	116 600	70 600	58 000	2	$\frac{24}{55}$	3 800	44.5	225	72
I-3. 1915	2	38″	121 600	70 600	63 000	2	$\frac{24}{25}$	3 800	44.5	225	...
I-4. 1917	20	38″	118 600	70 600	60 000	2	$\frac{24}{55}$	3 800	44.5	225	72
I-5. 1917	2	38″	113 600	68 100	55 000	2	$\frac{24}{52}$	3 800	44.5	225	...

High tension continuous current, motor vehicles. — Particulars.

Class and date.	No. in service.	Diameter of driving wheels in inches.	Weight in pounds. Total. T.	On the driving wheels. A.	Electrical equipment. E.	Motors, all with gearing. Number.	Gear ratio.	Power at rated speed. Tractive effort. F. H.	Rated speed.	H. P. per motor.	Seating capacity.
United-States. — Southern Pacific Railroad O. A. & B. Division : Continuous current, 1 200 volts.											
E-1. 1911	81	30″	109 400	109 400	23 600	4	$\frac{17}{64}$	11 680	18	140	116
Southern Pacific Railroad Portland Division : Continuous current, 1 500 volts.											
E-2. 1911	38	36″	100 000	...	...	4	$\frac{20}{54}$	...	25	...	60
Canadian National Railways (Montreal) : Continuous current, 2 400 volts.											
F-1. 1921	8	36″	120 000	120 000	39 000	4	$\frac{24}{26}$	9 600	23	150	68

(1) On these lines trains are generally made up of all motor cars and no trailers.

Motor vehicles. — Results of comparative figures.

Types or class.	E/T Ratio.	E/A Ratio.	T/H.P.H. Kgr.	A/H.P.H. Kgr.	E/H.P.H. Kgr.	T/F.H. Ratio.	A/F.H. Ratio.	E/F.H. Ratio.	Rated speed in kilometres per hour.
Single-phase.									
Switzerland. — Motor vehicles of the Lötschberg, 11 000 volts, 16.7 periods.									
...	0.37	0.66	60	33	22	...	...	...	...
England. — Midland Railway. — Lancaster-Heysham, 6 000 volts, 25 periods.									
...	0.33	...	90	...	30	...	...	...	...
London Brighton & South Coast Railway : 6 000 volts, 25 periods.									
...	0.33	...	88	...	30	...	...	...	...
Dutch Railways. — Rotterdam-Scheveningen, 10 000 volts, 25 periods.									
...	0.40	...	150	...	57	...	...	...	48
United States. — New York, New Haven & Hartford Railroad, 11 000 volts.									
G-1	0.22	0.22	118	118	33	17.7	17.7	5	37
G-2	0.40	0.40	105	118	43	16	16	6.3	37
G-6	0.36	0.36	...	...	...	...	...	...	...
G-7	0.30	0.30	93	98	41	16.8	16.8	5	32
New York, Westchester & Boston Railroad, 11 000 volts.									
H-1	0.46	0.76	193	115	90	...	...	...	91
Pennsylvania Railroad Philadelphia, 11 000 volts.									
Average	0.51	0.86	116	80	60	31	18.5	16	71
High tension continuous current.									
England. — Lancashire & Yorkshire Railway. — Manchester-Bury, 1 200 volts.									
...	...	...	67	...	...	...	...	...	42
America. — Southern Pacific Railroad O. A. & B. Division : 1 200 volts.									
E-1	0.22	0.22	88	88	20	9.3	9.3	2.5	29
Canadian National Railways (Montreal), 2 400 volts.									
F-1	0.33	0.33	90	90	20.5	12.5	12.5	3.8	37

The characteristics, which according to these results are best for comparing the different types of motor vehicles, seem to be the ratios of the weight of electric equipment to the adhesive weight, to the horse power, and to the tractive effort :

$$\frac{E}{A}, \frac{E.}{H.P.H.} \text{ and } \frac{E.}{F.H.}$$

Thus, as might be expected, the high tension continuous current is found in general, as far as motor vehicles are concerned, to have better coefficients than single-phase current.

As regards the figures relating to consumption per tkm., few of which have been supplied, one may be pointed out which merits attention. It is contained in the report of Mr. van Loenen Martinet, relating to the motor vehicles of the Rotterdam-La Hague-Scheveningen line, and gives 36 w.-h. per tkm. at the contact wire, fed direct without substations.

Now this relates to a flat line with curves of large radius, so that this figure gives close approximation to the consumption per virtual tkm. If we consider that it deals with motor vehicles, the motors of which drive the axles through the medium of gearing, it is permissible to compare with it the consumption arrived at by the Belgian State trials with motor vehicles fitted with *Gearless* motors mentioned at the beginning of this report.

One of the types with seating capacity for 64, weighed, empty, 50 t., and with passengers, 52 400 kgr. The line it ran upon, Antwerp-Lierre, is nearly flat, so that we may consider that the consumption given below as relating to the virtual ton.

COMPOSITION OF THE TRAIN.	Weight in tons.	Consumption, in watt hours, per virtual ton-kilometre.
Motor vehicles alone (stops at all stations).	52	17 to 20
Motor vehicles hauling one trailer (without stop)	67	Average : 16.1
Motor vehicles hauling two trailers (stops at all stations) . . .	83	17.8 to 20.1

These figures also include the current used for working the brake and whistle.

Admitting that the great difference between these figures and that shown by the Dutch motor vehicles is partly due to the nature of the current, it is possible to see the very great advantage of the absence of gearing.

It is well known, moreover, that the gearing of tramway motors absorbs 6 to 10 % of the energy.

Differences in efficiency of the more powerful motors used on railways are shown below :

POWER.	Motors with gearing.	Motors without gearing.
Full load	86.5 %	89 %
25 % load	75 %	88.5 %

Trials at the works, with gear wheels in good condition. The mean tractive effort after starting often remains in the proximity of 25 %.

Taking a difference in mean consumption of energy of 10 % at the trolley wire, if there is only a 20 % drop in the cable from the central station up to the sub-station, the loss of energy will be 12.5 % with high tension.

To this must be added the difference in maintenance costs.

If therefore the nature of the current

had an effect on the ease of construction of the *Gearless* motors, it would be an important argument in its favour, since it is certainly more economical in electrical energy and upkeep.

D — Financial results.
Comparison with steam traction.

a) Most of the reporters regret not being able to supply sufficient financial information to enable them to point to one of the systems under discussion being the best from the point of view of first costs and running expenses.

Mr. Gibbs, however, states that in first cost there is an economy of 10 % by the use of single-phase in comparison with continuous current, and considers it slightly less expensive to work. As this advantage cannot result from the working of the single-phase motors, it is no doubt attributable to the transmission of energy at very high voltage, which allows a greater distance between the sub-stations and so reduces the cost of their supervision and upkeep.

In contradiction to this, Mr. Sabouret gives a case in which this factor of economy gradually vanished on account of the means that had to be adopted to overcome induction, which caused a drop in voltage, and finally necessitated the fixing of suitable apparatus to boost it up again.

As this relates to an American installation, it is only right to quote the opinion of engineers in that country on this subject as reported by Mr. Gibbs. First of all he does not admit that it is certain that continuous current is not harmful as regards induction in telegraph and telephone circuits, and the saving in the United States would not counterbalance the advantages gained from very high tension currents. This is because the expense would be divided up between the telegraph and telephone companies and the owners of the railway, when, of course, the telephone and telegraph lines are close to the track, which is rarely the case in America. Finally, he concludes, it is rather a technical problem that experience will finally solve in the best interests of both parties.

At present, therefore, there is no absolute criterion of a financial nature to determine the choice between the various methods of electrification. At the same time, a given system which is economical in the transmission of energy necessitates the use of motors more expensive to buy and maintain, which is a drawback increasing proportionally to the number put on the line (1);

b) As regards the comparison between the two methods of traction, electricity or steam, may I be allowed to interpret in a somewhat paradoxical form an opinion apparently shared by my colleagues who have had to deal with question VIII : the more competent a railway engineer connected with electric traction becomes, the less he considers it susceptible of being

(1) This assertion has already been put forward by Mr. J. A. Davis in the *Street Railway Journal* of the 7 September 1907, showing the comparative financial factors of the different systems, as follows :

Method of transmission	Continuous : 600 volts.	Continuous : 1 200 volts.	Single-phase : 6 600 volts.
Sub-stations, feeders, contact line; per mile of single track, in dollars	10 670	9 200	7 170
Cost of a motor vehicle, in dollars.	10 800	11 800	13 800
Upkeep of the equipment of the motors per car mile, in American cents	0.4	0.5	0.6

extended economically to all kinds of railway service on all the lines of the large railway systems. The steam tractor will keep its place a long time yet in the working of railways.

In those regions, however, where « white coal » is abundant, also on lines of varied gradients, with large traffic necessitating the multiplication of locomotives for loads relatively small, or else on those lines where the ventilation of long tunnels has to be considered, and in cases of terminal stations where there is a heavy suburban service causing much shunting, electric traction is an advantage, as has been shown by the reporters, independent of whether hydro electrical generated energy is available or not. Economy also arises from the fact of the capacity of the lines being increased, and thus doubling them is avoided. On long inclines electric traction causes the running to be more regular, being free from the troubles experienced with steam locomotives, which are unable to give a maximum output over long periods. According to the picturesque expression of Mr. Sabouret, « the electric locomotive, on the contrary, is never out of breath ».

In addition, as clearly shown by the same reporter multitraction allows the power being applied at the most suitable points of the train and so renders the running more satisfactory.

Small passenger trains of motor-coaches and worked on the « multiple unit » system serving the neighbourhood of large centres cause, by their frequency, an increase in traffic, and that system which goes in most for this frequency of light motor vehicles will be rewarded by certain success.

Table IV of Mr. Donati's report which gives a comparison between steam and electric traction in Italy is very conclusive.

As might be foreseen, it is the cost of power that plays the principal role, coal working out to 13.15 lire for 100 virtual tkm. for steam traction, and only 1 lire 54 to 1 lire 60 for electric traction.

E — Conclusion and questionnaire.

The above general synopsis shows clearly that without wishing to limit the range of questions that will be put at the Congress at Rome on the electrification of the large railway systems, it will be possible this time to direct the discussions of the 2nd section to subjects of practical interest put forward by the reporters.

1. — From the statements of the reporters taken as a whole concerning the relative value of the principal forms of energy applicable to the electrification of railways, we are inclined to conclude that the question « which is the best » will no longer be asked, but rather « under what circumstances should any one of them have preference ».

2. — The point on which all the reporters seem to agree, is the uselessness of standardisation of the current in the contact wire on account of the ease with which locomotives may be changed at the frontiers of the different countries. This question might raise discussions of a political nature which are against the custom of the Railway Congress.

3. — One point, on the contrary, does not appear to be absolutely advisable, and that is the proposal to standardise the system of traction over the whole of a large country like France for instance. It is absolutely certain that the Southern lines in the neighbourhood of the Pyrenees must electrify at 1 500 volts continuous current, if one of the alternative types could be employed with greater

advantage, bearing in mind that there are other considerations than those purely technical.

The Italians show themselves to be more eclectic, and the Americans have no thought of standardising one special system. The English make concessions to pre-existing installations provided that installations at joint stations where two systems meet allow of the changing of the locomotive.

4. — It is unanimously desired that the methods of compiling particulars relating to economy should be standardised, not by a system of book-keeping of each electrified group, but what might be called by an *international account.* We hope that a table of comparative *financial particulars will be discussed at a sectional meeting.*

It would be convenient to adopt for this purpose a common standard by which all particulars and results both technical and financial can be equally measured, for exemple, *by virtual ton-kilometre, which is equivalent to a ton-kilometre on a straight level line.*

Here are a few other questions inspired by the reports :

5. — *Is the longitudinal catenary suspension preferable to the simple transverse suspension, technically and economically?*

6. — *Has the use of three-phase current at 50 periods given rise to practical results justifying its extended use for main line railways?*

7. — *What type of current is the best for use with the Gearless motors, permitting the latter to keep their known advantages?*

8. — *Is multitraction more suitable with one type of current than another?*

It is of course understood that the above questions are only for guidance and are by no means the only ones that might be put.

[656 .212 & 725 .32]

REPORT No. 3

(countries using the English language)

ON THE QUESTION OF GOODS (FREIGHT) STATIONS (SUBJECT X FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION), [1]

By Howard G. KELLEY,
PRESIDENT, GRAND TRUNK RAILWAY SYSTEM OF CANADA, MONTREAL, QUE.

Figs. 1 to 3, pp. 803 to 804.

In order to secure information on the different points raised by the title of this paper, a questionnaire was prepared and submitted to 29 American railways, 42 British railways, 9 Indian and 2 African railways.

Replies have been received from the following :

American railways :

Southern Railway System, Washington, D. C.;
Norfolk & Western Railway Company, Roanoke, Va.;
Pennsylvania System, Philadelphia;
Delaware, Lackawanna & Western Railway Company, N. Y.;
The Long Island Railway Company, N. Y.;
The Central Vermont Railway, St. Albans, Vt.;
Erie Railway Company, New York;
Lehigh Valley Railway, New York;
New York Central Lines, New York;
The Staten Island Rapid Transit Railway Company, N. Y.;
The Baltimore & Ohio Railway Company, Baltimore, Md.;
The Hocking Valley Railway Company, Richmond, Va.

British railways :

The Highland Railway, Inverness, Scotland;
Glasgow & South Western Railway, Glasgow, Scotland;
Great North of Scotland Railway, Aberdeen, Scotland;
The Liverpool Overhead Railway Company, Liverpool, England;
Furness Railway, Barrow-in-Furness, England;
North Staffordshire Railway, Stoke-on-Trent, England;
Great Western Railway, London, England;
South Eastern & Chatham Railway, England;

[1] This question runs as follows : « Organization of the receiving and the delivering stations, so as to accelerate their business. Arrangement of the buildings and tracks so as to simplify shunting switching) operations and handling, particularly as regards goods in bulk. Mechanical appliances. »

Railway Clearing House, London, England;
Dublin & Southeastern Railway, Dublin, Ireland;
Tralee & Dingle Railroad, Tralee.

Other railways :

South African Railways & Harbors, Johannesburg;
South Indian Railway Company, London, England;
Bombay, Baroda & Central India Railway Company, London, England;
Madras & Southern Mahralta Railway, London, England;
India Railway Conference Assnn.;
Nigerian Government Railway, Lagos, South Africa.

A copy of the questionnaire is published as an appendix to this paper.

The problem of freight handling at railway stations, or more generally railway terminals, is one of rapid, efficient and economical transfer of freight from one form of transportation to another. The collecting of freight from primary sources, such as road stations, mines, mills, etc., is a comparatively simple problem and does not call for any particular attention in a paper of this nature. Its transfer and delivery at terminal points, however, is one of the utmost importance, calling for the provision of the best possible facilities and maximum efficiency of organization that this important phase of transportation may be handled in the most economical manner.

The subject, as thus limited to terminals, divides itself into five distinct headings according to the methods of delivery and the form of carrier to which transfer is made; these are :

1° General yards;

2° Team delivery yards in which car load shipments are transferred direct to and from road vehicles;

3° Freight houses, inbound and outbound, in which package and L. C. L. (less than carload) freight is handled between rail and road vehicles or from car to car;

4° Private sidings on which loading and unloading is done by shipper and consignee on his own property direct to and from cars;

5° Water terminals at which freight is transferred between rail and water carriage.

Under each of these subdivisions there are two distinct but closely related phases which will be treated (in so far as it possible to divide them), separately: the first is the provision and physical layout of facilities for properly handling the business offering, and the second the proper organization of staff for the efficient operation of these facilities.

General yards. — The first requisite of a terminal is a general yard in which the cars in arriving-trains are classified for delivery to team tracks, freight houses, private sidings, piers or to connecting roads, and outbound cars classified and marshalled into trains for road haul. This general yard must also provide proper facilities for the cars of motive power, car repairs, etc.

The details of such a yard do not properly come within the scope of this paper, but as the whole efficiency of the terminal depends on its proper location, layout and operation, it is important to touch upon its general requirements.

The location of the general yard should be as convenient to the terminal delivery points as possible to avoid long transfer hauls through congested areas, but as a

yard of this nature must occupy a large area, it will generally be necessary to locate it on the outskirts of the city, sometimes as much as 15 or 20 miles from freight house, team tracks, etc. In such cases it is convenient to have small district yards closer in, from which cars may be delivered and received at the various loading and unloading points, and in which final classification may be made. The main yard for inbound traffic should have facilities as follows :

Receiving yard. — The track capacity of the receiving yard should be sufficient to hold at least all trains arriving during any one hour of maximum business. The individual tracks should be long enough to hold without a break the longest trains ordinarily received, and to accommodate with only one break the maximum train received.

Separating yard. — The separating yard is where the first breaking up of the train and distribution of cars is effected. The classification made in this yard is generally by delivery districts. It should be located in advance of the receiving yard and in such a position that cars can be readily moved into it. The number of tracks in the separating yard is governed by the number of separations to be made and the length of these tracks by the number of cars in each separation.

Classification yard. — This is the yard in which cars placed by districts in the separation yard are switched in delivery order. It should be located in advance of the separation yard in such a way that cars may be readily moved into it from any track of the latter. It is well to avoid unusual length of classification or sorting tracks. Where classifications are numerous the provision of a track for each classification should not be attempted. If more classifications are necessary than tracks can be conveniently provided for on one lead, a second yard should be provided, in the case of an outlying yard serving district yards closer to the centre of the terminal, it may be advantageous to take cars direct from the separation yard to the district or sorting yards and do the final classification there. A decision as to where final classification is to be made will depend upon facilities available and number of cars for each classification.

Departure yard. — For inbound traffic, if the classifications are large enough, cars may be taken directly from separation or classification tracks by transfer engines, or they may be assembled on a departure track by a switch engine. The provision of special departure tracks will depend on local conditions. The departure yard, if provided for inbound traffic, should be in advance of the classification yard and conveniently situated for the direct movement of cars from the latter to the departure track.

The arrangement of yards and tracks for outbound traffic is similar to that described for inbound but arranged in reverse order.

Storage yard. — A storage yard must be provided to hold cars on consignment, and which, on account of other traffic and operating conditions, cannot be immediately delivered. The holding of loaded cars is most undesirable but is often unavoidable, and, therefore, storage tracks must be provided in order that the « hold » cars may not interfere with the switching and delivery of other cars. The storage yard to be convenient to the other yard tracks and of sufficient size to meet local requirements.

Operation. — The actual practice in switching and placing cars is a matter that must be governed by the peculiarities of the traffic and the physical characteristics of the yard, and can therefore only be described in a general way.

When a train arrives in the receiving yard, the engine and caboose are at once cut off. The conductor delivers his manifest and switch list to the yard clerk who prepares a card for each car which by shape color or symbol denotes its final destination. Another clerk attaches these to the individual cars. While the cards are being prepared and attached, the cars are inspected and any which have to be repaired marked for the repair track.

After inspection and marking, a switch engine takes charge and runs the cars into the separation yard according to their destination by districts. From the separation yard, they are taken by another switch engine to the classification yard and switched in delivery order, or where this final classification is done in district yards, they are taken by a transfer engine to the proper district or sorting yard and the final classification made in that yard by the district switch engine. After final classification, they are delivered to the tracks where they are to be unloaded.

Movement of cars within the general yard is not usually reported, but the conductor of the transfer train reports all cars moved in and out by him and when delivered, as does also the conductor of the district switching engine report all cars placed and lifted from particular locations. In this way a record is kept showing the movement of the car from its arrival into terminal to the time of its departure.

Team delivery yard.

Location. — The location should be as near the industrial centre of the city as possible. The advantages are ability to meet competition from water routes where they exist, and other railways. The team haul of a few city blocks is often a deciding factor in the routing of freight. Against these advantages of a central location must be balanced the higher interest charges and taxes on such property, as well as the expense of gaining an entrance. With a new road, an old road seeking new business, or one having outgrown its present facilities, the question to be considered is whether a central location will bring sufficient business to justify the higher cost. Generally it will be found that the expenditure of considerable sums are justified in providing a convenient and central location. The location with respect to other facilities is also important from an operating point of view. Proximity to other facilities makes it possible to handle the business with one supervisory staff, and lessens the amount of switching necessary.

Layout. — The general layout is usually restricted by the size and shape of the property available, making what might otherwise be an ideal, unattainable. The size will be governed by the business offering at present and the necessary provision for a reasonable increase.

Trackage where possible, should be provided for at least one day's business, and preferably two to allow for delay in loading and unloading. Several tracks, holding from 15 to 20-40 foot cars, are preferable to long tracks, as they tend to quicker handling by switch engines, and a minimum interference with draymen.

To save space, tracks are generally laid in pairs with a roadway between. The distance between tracks for American cars is from 12 to 13 feet and for British cars from 11 to 13 feet. The distance between pairs of tracks ranges from 35 to 60 feet, leaving clear roadways of from 27 to 52 feet. The governing principle is that a motor truck or wagon, backed against a car for loading, should not block the roadway. As modern motor trucks of large capacity run to extreme lengths of 40 feet, a clear roadway of 52 feet is none too wide and should be provided in designing future yards.

Tracks connected to ladders at both ends are preferable from a switching viewpoint, as it is possible to pick out cars when loaded without disturbing the whole string, but are seldom practicable on account of space limitations. The extra convenience will not justify any considerable expenditure for land. Approximately 50 % of the roads answering the questionnaire preferred stub end to through tracks.

The paving of the roadways should be of permanent type and design for heavy traffic. Ample drainage should be provided.

The use of special appliances such as car pullers, transfer tables and turntables, are unknown in American team yards. They are used in British yards where space is so limited that their use cannot be avoided. In yards where, on account of high property values, it is of importance that all space be utilized to best advantage, or where approach is impossible in any other way, the installation of turntables and transfer tables deserves consideration.

Track scales are seldom provided in team yards, the custom being to weigh the cars at the first classification yard through which they pass after despatch. They can be installed to advantage only in very large yards. Where so installed, they should be near the main load to facilitate weighing.

Wagon scales are provided at important yards, they should be of sufficient capacity to accommodate the largest motor truck in common use. For convenience they should be located near the main team entrance and convenient to yard office.

The extent to which platforms, ramps, etc. (for convenience in loading automobiles, farm machinery, etc.), are provided, will depend on the extent of this class of traffic handled. Where considerable, ramps and platforms provide a convenient means of loading.

In yards receiving or shipping heavy pieces of freight, some mechanical means of handling is essential. The elaborateness of this machinery will depend on the weight of pieces and the extent of this class of business. It will range from a hand operated crane to an elaborate gantry crane, spanning a roadway and several tracks. For a large installation the most useful is an electric gantry crane running on rails placed on the roadway side of the running tracks, spanning the roadway and having a cantilever arm over each pair of tracks. On this bridge is mounted an electric travelling hoist of 20 to 30 tons capacity.

In some cases special yards are provided for special commodities or certain parts of the general yard set apart. It is often advantageous to designate special places for fruit, vegetable and farm produce, or special yards for handling coal, lumber and other heavy commodities. The extent of this practice will be governed entirely by local conditions and no fixed rule can be laid down.

The operation of the team yard presents no special difficulty. Consignees are notified of the arrival of their cars in the usual manner, and on application to yard office, are given their location. If a sealed car, a clerk accompanies consignee when opening and checks out contents as it is unloaded. Loading and unloading of cars placed on team tracks are done exclusively by shippers and consignees. The most advantageous time for placing and removing cars is before unloading commences in the morning and after working hours in the evening. If more than these two shifts are necessary, they should be made at noon, so as to disturb the carters to as small an extent as possible.

Freight houses.

Location. — The same factors which govern the location of a team yard are operative in the choosing of a location for a freight house. The location with respect to the general or district yard should be such as to allow quick handling of cars to and from the house.

General design. — At a small terminal one house for both inbound and outbound business will serve, but where the business is heavy, instead of having a large house for the handling of both classes of business, it will be found advantageous and economical to provide separate houses for inbound and outbound business.

The exact point at which it will pay to establish separate houses is difficult to determine. The answers to this question showed wide differences of opinion, some roads stating that a total business of 100 tons per day would justify separate houses, while other roads claimed they were not justified until the business amounted to 600 tons per day.

The correct answer is probably about 300 tons, but much depends on local conditions. Other roads state that where business necessitates a shed over 400 feet in length, that separate houses should be provided. No general rule can be laid down, each situation must be treated on its merits, proper consideration being given to all local factors balancing increased investment against economy in operation.

Inbound houses. — The purpose of an inbound house is the transfer of package and L. C. L. freight from car, to road vehicles. Incidental to this transfer and consequent upon road vehicles not being available for direct transfer, a certain amount of storage is necessary, involving a sorting and piling of the freight. This condition is especially noticeable where delivery is done by the consignee and not by the railway, as is the almost universal custom in America.

If direct transfer from car to wagon or truck were possible, an extremely narrow shed would be advisable giving a short trucking distance, but the requirements of sorting and storing call for a certain minimum floor area, and this with a narrow shed would require one of extreme length.

The length is limited by practical trucking distance, as freight from any car has to be trucked to its proper location to await delivery. The problem then is to provide the necessary floor space by balancing length against width until a layout is obtained which will permit of maximum economy in operation. The American Railway Engineering Association recommends 50 feet as a good average width, while the American Railways replying to the questionnaire gave 35 feet as a minimum and 75 feet as a maximum.

The concensus of opinion as to length was that it should not exceed 800 feet for efficient trucking. This distance is for hand trucking but where tractors and trailers are used it can be exceeded somewhat.

An investigation made by the New York Central Railway showed that for proper operation 135 square feet net floor space was required for each ton of freight handled per day, and that, allowing for aisles, etc. 150 square feet gross was necessary, also, that the average maximum freight which could be handled at any one door was 15 tons and this only with wide driveways and the use of motor trucks.

Taking as an example a point where 600 tons of inbound freight is received per day, and using the figured floor space of 150 square feet per ton, a total area of 90 000 square feet is required. If 75 feet is assumed as the maximum width, the length must be 1 200 feet. If this 1 200 feet is assumed as the maximum practical length, which it approaches, the capacity of the house can only be increased by adding more floors with the consequent additional expense of elevator service, etc., or building another freight house.

The following relations between various factors of design for warehouses where the turnover of goods is moderately rapid are taken from *A. R. E. A. Bulletin*, vol. 23,No. 239, September 1921, and although not representing exactly limits of design are indicative of proper relation which should exist, based on experience of warehouses studied :

1° One elevator should be provided for each 40 000 square feet of warehouse space served;

2° Shipping platform area should be 4 % of warehouse storage floor area;

3° There should be one car length of siding track for each 17 600 square feet of warehouse storage area;

4° There should be one foot of tailboard frontage for every 1 100 square feet of warehouse storage area;

5° There should be 16 feet of tailboard frontage for each car length of siding.

A platform on the team side of the inbound house has little or no advantage and is not usually built, but on the track side a continuous platform 8 to 16 feet wide should be provided for trucking. Its provision eliminates the necessity of spotting cars exactly opposite the doors of the freight house, and the confusion of trucking inside the building. If a platform is not so provided, the side of the house should be continuously open and without posts, the doors being arranged to slide by each other enabling an opening to be made wherever a car door stops. This arrangement is in effect a platform and necessitates a continuous clear space along the inside of the house, thus cutting down the floor space available for storage. It is considered the better practice to provide a platform.

Tracks serving the house are generally provided in pairs parallel to the long side of the house. Twelve foot centres are usual. Closer spacing will not allow refrigerator car doors to be opened and a wider is unnecessary. Where more than two tracks are necessary, the pairs should be separated by platforms of about 12 feet in width. With these, every car can be unloaded directly to a platform which is a convenience and avoids expensive switching in an effort to spot car doors directly opposite each other. Their provision also makes unnecessary straight line trucking through several rows of cars, in which truckers are at all times liable to meet causing confusion and delay.

At intervals of at least 400 feet some form of bridge should be provided over the tracks between these platforms and the freight house platform to save trucking distance and eliminate the necessity of trucking through two cars of different floor heights. These trucking bridges may be removable platforms resting on supports placed between the track, or they may be of the bascule type either hand or power operated. The space between bridges should be of such length as to accommodate an even number of standard cars.

Roadways should be of sufficient width to allow the longest vehicle in use, to be backed against the door without completely blocking it for the passage of other vehicles.

Outbound houses. — The purpose of an outbound house is the transfer of package and L. C. L. freight from road vehicles to cars. As cars are generally available for direct loading, little storage is necessary and the width can be made narrower than inbound houses.

The American Railway Engineering Association recommends 30 feet as a good average width. American railways replying to the questionnaire gave 20 feet as a minimum and 55 feet as a maximum width, but generally favored a width of 35 feet.

Wide houses entail unnecessary trucking and if too long, require too great a train length, which either stops housework while the set-up is being changed or detains cars. Freight houses have been built up to 2 000 feet in length but usually are failures in practical working, unless the track layout is such as to enable part of it to be worked without disturbing the remainder.

The requirements as to tracks, platforms, etc., are practically the same as for inbound houses, except as to provision of a platform on the track side which is not as important as in the case of inbound houses, on account of the trucking being direct from teams to cars, it has however, the advantage of not requiring such close spotting of cars.

There is a difference of opinion as to the advisability of putting a narrow platform on the receiving side of outbound houses. A certain advantage is to be gained in enabling teamsters to get rid of their loads quickly, on the other hand it requires a closer check and a larger force of receiving clerks than where freight is unloaded directly into the house. Where numerous doors are provided a platform is certainly unnecessary.

It is advantageous to place inbound and outbound houses opposite to each other with tracks between and a connecting platform at the end. This enables freight to be transferred directly from inbound cars to outbound cars where necessary, and facilitates the switching of empty inbound cars to outbound platforms to be loaded. The houses can be under one general supervisory force with offices located convenient to both.

Where outbound business requires a great number of cars, the average trucking distance can sometimes be reduced if the freighthouse is built at right angles to and back of a series of tracks built in pairs with covered platforms between.

Outbound houses should be provided with scales at frequent intervals, say 50 or 100 feet apart, and arranged along the side where delivery is made. The beams should be parallel to the wall so as to leave no obstruction to trucking. Automatic dial scales furnishing the weight on a printed slip are a great convenience and speed up weighing.

As long as a road has only one terminal in a city, the matter is comparatively simple, but when business outgrows this condition and additional freight houses are necessary, operating troubles begin. It becomes necessary to establish transfer service between each inbound house and outbound house to get the freight going beyond the station to the proper outbound house for reloading.

Ordinarily, a car is placed at each inbound house to move this freight daily or oftener. These are called trap cars. The Cleveland, Cincinnati & Chicago Railroad has met this problem by means of motor trucks with demountable bodies. The system adopted is more fully described later.

The type of floor adopted for a freight house is one that should be given proper consideration A poor floor impedes trucking and results in increased cost. A hard maple floor, laid over treated softwood, is the most satisfactory for trucking. Asphalt is good and has the advantage over wood of being fire resisting, in wet weather, however, it gets slippery. Concrete chips at joints, and after being in use for some time, becomes rough and difficult to truck over. Hardwood has none of these disadvantages but it must be carefully laid to give good results.

A slight inclination in the direction of greatest movement is an advantage, especially where hand trucking is the rule.

Freight transfer stations. — In connection with freight houses, it is often necessary to provide freight transfer facilities for the purpose of transferring freight from one car to another in order that it may be consolidated in cars for one destination.

The location should be at a point where traffic converges or diverges, and at such places both purposes may frequently be served at the same transfer station.

A covered platform with one or two tracks on both sides is usually provided. It is not desirable to have more than two on each side of the main platform. If more are required additional platforms should be provided outside the first two, so that the movement of truckmen may not be impeded. Tracks should be open at both ends to facilitate movement and make it possible to shift or place cars with the least disturbance and interruption.

The length of the main platform should not exceed actual requirements and the width should be not more than 24 feet so that the distance to be travelled may be kept within reasonable limits, 14 to 16 feet platforms roofed over will be found most suitable for general transfer business, but in fixing the width, consideration must be given to the class of commodity to be handled. Cotton and other heavy baled goods can be handled to advantage on a platform from 10 to 12 feet wide. The main platform should be covered and the height should be that of a car floor when standing on the track alongside. For American cars, this is about 4 feet.

Multiple storied freight houses. — So far, only single storied freight houses have been dealt with. The value of real estate in large cities, artificial topographical conditions, due to grade separation, etc., and the necessity of increased space for storage, especially in inbound houses, have forced the consideration and building of freight houses of more than one story.

The subject divides itself into the following subheads :

1° Two track level freight houses as

compared with single level freight houses;

2° Freight houses with tracks at one level and delivery at another;

3° Multiple storied freight houses or the operation of storage warehouses in connection with freight houses.

1° This type is practically unknown in America, but the increasing value of real estate in our large terminals favors its consideration. Their operation will undoubtedly be more expensive than single level terminals, but the economy in fixed charges may possibly result in a lower total cost per ton.

2° This type of freight house with tracks and delivery on different levels is attracting increased attention for large terminals and in providing new facilities, must be given serious consideration. The factors involved are necessity for expansion of facilities which is otherwise impossible or impracticable except at large expense for additional land; separation of grades, which with single level houses would involve steep approach driveways; the reduction in the congestion of vehicles and shortening of trucking distances, the latter being one of the principle factors in the expense of operation.

Where conditions permit of choice between single or multiple level designs, selection must be based on these considerations :

1° Value of land;

2° Construction cost;

3° Present and future business;

4° Operating costs;

5° Operating capacity.

As with the two track level house, operating costs will undoubtedly be higher, but total cost, considering fixed charges may be found to be less.

A study made in 1916 by the American Railway Engineering Association, showed that the average handling cost in two storied houses was 10 % in excess of the average for a single storied house.

The almost universal arrangement is to have both tracks and teamways run longitudinally with the building, with platforms on the upper level directly over those on the lower level.

3° Railway freight warehouses are now being used extensively. They combine railway and commercial purposes. Facilities are provided for cars and teams on the lower one or two floors, and other floors are rented to merchants and others for storage. Inbound freight can be sent direct to storage, and outbound direct to car platform for shipment. Considerable time is saved and considerable heavy trucking or teaming eliminated between freight house and warehouse, valuable city property is utilized to the utmost and thus a reduction in fixed charges is made.

Some roads do not favor going into the warehousing business, but where freight houses occupy land of high value, it is very desirable to develop revenue from the area occupied and offer economy to the shipper, providing the normal business of the road is not interfered with.

One objection that has been made to the proposal is the confusion of teams and in elevator service serving both freight houses and warehouses. This objection has been overcome by the provision of elevated roadways to serve the upper stories, access to them being gained either by ramps or large elevators capable of taking the heaviest motor truck or dray commonly used.

One of the first considerations in two or more level houses is adequate provision for handling freight between floors. Inclined conveyors, gravity chutes, esca-

lators, etc., have been proposed and are used in numerous cases, but the principle means employed are electrically operated elevators. For economical operation these should have large lifting capacity and platforms large enough to hold a train of trailers. The doors at the various floors to be arranged on both sides to permit one train of trucks to be run off and another on without interference.

Automatic elevator service is a remarkable development of elevator equipment which has lately been applied with marked success is some of the busiest railway and commercial warehouses. No operators are required on the elevator cars, thus eliminating a large wage item and innumerable slight delays due to the personal equation of a number of employees operating. One despatcher at a desk, equipped with a battery of signal lights, can control all movements of as many as 30 cars. The elevators are equipped with automatic floor levelling devices and other safety appliances. Another type does not require a despatcher but is operated by means of push buttons, adjacent to the doors of elevators.

Operation of freight houses.

Handling inbound freight. — The personnel for the operation of an inbound freight house consists of a foreman, in charge of the house and responsible for the correct unloading, checking and delivery of freight to consignees, as many assistant foremen as are necessary, a clerical staff, checkers, callers, truckers, delivery clerks and laborers.

An inbound house is usually divided into sections, alphabetically or numerically with special sections for consignees whose business warrants it. Each section is given a « location symbol » which is used in stowing the freight and in subsequently locating it for delivery.

When a car is placed ready for unloading, a checker supplied with the waybills or special tally sheets, opens the car, making a careful note of the seal numbers and their condition. The caller, as each piece is loaded into a truck calls to the checker its description and markings to enable him to identify it on waybill or tally sheet. Each piece is marked with the car number, date of unloading and « location symbol », which gives to the trucker its destination in the house. The checker enters on his tally sheet in the proper column the « location symbol » which is later shown on freight notice and warehouse receipt to enable the delivery clerk to readily locate the shipment.

Each shipment consisting of two or more packages should be stacked together, with marks exposed. In the case of large shipments the checkers should send with the first truck load a slip showing total number of packages in shipment to enable proper provision to be made for piling it together.

Careful checking, handling, with prompt and proper stowing inside the warehouse is necessary to protect from weather damage, and loss from theft. Overs, shorts, damages and thefts must be reported promptly with full particulars as to car number, seals, date, etc., for which special forms are usually provided.

As soon as freight is unloaded, waybills or tally sheets are returned to office and expense bills made out, usually in quadruplicate, one copy sent to consignee as notice of arrival, one copy sent to cashier, one to delivery clerk and one retained as office copy. These bills show date of shipment, date of arrival, number and kind of packages, weight and charges and freight house location symbol.

The consignee upon receipt of notice pays charges to cashier, who receipts the bill which then becomes an order on delivery clerk for the freight. On presentation of this order at freight house door, delivery is made and receipt taken.

All records pertaining to the unloading of freight at destination should be filed in proper order for reference.

System used to notify shipper of arrival of freight. — One of the troubles in a freight station is the enormous amount of impatient telephone enquiries regarding freight arrivals. This can be successfully met, at any large freight office where the clerk at the telephone has constantly before him copies of the arrival notices made out for each consignee on the arrival of freight, and these, being arranged alphabetically, enable him to answer a telephone enquiry from any person or firm in 20 seconds or less. The notices are classified not only under each letter of the alphabet, but also, when necessary, by sub-divisions. When waybills arrive, the clerk who makes the expense bills uses carbon sheets and makes four copies at one writing.

One of these copies, the « No. 4 », which is called the office record, is handed at once to the clerk at the telephone, who assorts all of the sheets received and puts them in proper pigeon holes. Then on receipt of an enquiry, as quickly as he can turn and catch the letter on the horizontal line corresponding to the first letter in the name of the shipper, and the second letter in the name on the perpendicular line, he can immediately locate the proper pigeon hole and get the necessary information.

The « No. 4 », being a carbon of the « No. 1 » all information as to date of arrival, date of shipment, number and kind of packages, weight and charges, are right before him, so that all questions relating to the shipment can be answered intelligently. In the event of goods not being in, and consignee wishing to be advised by 'phone when they do arrive, a pink slip is used, the information being inserted as to date shipped, kind and quantity of goods and the consignee's 'phone number. When the goods finally arrive and the « No. 4 » are being distributed into their proper places, if a « pink » is discovered in a pigeon hole, the consignee is immediately notified. If consignee asks, « when will our goods be delivered », this may be answered as quickly as any of the other questions. When the delivery clerk passes over the sheets to the cartage company, the « No. 3 » is retained for the Accounting Department, but before these are passed to that Department, the enquiry clerk takes them, and in spare moments takes out the corresponding « No. 4 » and places it in the « Z » space at the bottom. All he then has to do when he fails to find a « No. 4 » in its proper place is to look in « Z » and he is then in a position to know whether the shipment has passed out and is on its road for delivery. At the close of the day, the « Z » are taken out, tied together dated and sent to the Record Room. If taken from one pigeon hole after another in regular order, they will be found when tied, in alphabetical order. If a consignee has inquired several times and it seems desirable to start a tracer, the « pink » with the information obtained at the time of the first call is still in the pigeon hole and available for quickly making a memorandum which can be handed to the tracing clerk, thus saving the consignee all unnecessary trouble.

Handling outbound freight. — The personnel in an outbound house consists of

foreman, route clerk, receiving clerk, truckers and stevedores.

The teamster with bills of lading properly prepared goes first to route clerk who marks on bill spot number of car in which freight is to be loaded, and if possible directs teamster to the freight house door which is nearest to that car. At the door the receiving clerk checks shipment with bill of lading and signs receipt for freight. He must be careful to see that each package is properly described in bill of lading, properly packed, properly addressed and in every way prepared to insure against loss or damage in shipment. In case of corrections being necessary on original bill of lading, alterations should be made and signed by shipper's agent.

To avoid confusion an independent bill of lading should be furnished for each dray load.

To save handling and encourage teamsters to transfer freight directly from team to trucks a liberal supply of trucks should be kept at the doors at all times, separating freight for each destination to ensure accurate loading.

All shipments not in standard packages should be weighed and weight marked on way-bill.

In the handling of freight from time of receipt to final packing in car a positive accurate check is necessary to stop loss and prevent loading in wrong cars. The following plan known as affirmative loading is one of the best in operation to-day.

As the freight is received over the bulkhead from the teamster, the receiving clerk chalks the packages with spot, board or loading number. When loaded on the trucks for movement to the car, a ballot is handed the truckman bearing date, spot, board or loading number, number of packages in the shipment, and number of packages on the truck, pro number, truckman's number and the clerk's initials (a space is also provided for the stowman's initials or number after the freight has been stored in the car).

The loaded truck is then moved and dropped inside or just outside of the car door as the facilities may permit with the ballot secured to the truck. The truckman then picks up an empty truck and returns to his loading or receiving clerk.

When the stowman or stevedore arrives to release the truck his first duty is to verify the spot, board or loading number chalked on the freight and shown on the ballot, he then wheels the loaded truck into the car, removes the ballot, checking the contents of the truck against the ballot record.

The ballot is immediately deposited in a receptacle hanging inside or just outside the car door.

If a truck is found to have been brought in front of a car in which the freight should not go forward, it must be sent to the centre of the platform and reported to the foreman for correction.

As an additional safeguard against erroneous loading, the platform foreman or some designated employee, must inspect the ballots throughout the day in order to catch mistakes that might be made in the loading.

A final verification of the ballots must be made at the close of the day's work, when they are to be lifted and banded together in car order. One man must be designated to handle the shipping orders from the platform to the billing department in order that the responsibility for delays and irregular handling may be located and corrected.

Trucking systems. — There are two systems of hand trucking in general use,

in the first each trucker has his own truck, makes round trips with it between the loading and unloading point; the second which is known as the drop truck system, provides 5 to 15 trucks for each trucker and when a man brings his truck he does not wait for it to be loaded or unloaded but drops it at a designated place, picks up another truck and takes it to destination. This system eliminates much of the empty truck movement and enforced idleness of truckers which prevails under the first system. Where tractors and trailers are installed the same system can be used to great advantage. In outbound houses freight is loaded directly from drays to trailers which are picked up by tractors making regular rounds delivering empties and picking up loads.

Piece work system of handling freight. — Many freight and transfer stations are introducing, with varying success, the system of handling freight and paying for it on a tonnage basis, an application of the « piece work system ». The success of this method and the details for working it depend largely on the class and cost of labor and the kind of commodities handled. There are various methods under which this may be worked, among others is that of taking a careful record of the handling of the freight and figuring on the cost per ton. One rate is usually made for package freight and another for carload or bulk freight, and at times special rates are made for certain kinds of commodities which run heavily. A record is then kept of the number of tons handled by each laborer. In some cases the men pool the work and the amount is paid in a lump sum to the foreman or leader of the gang employed. The work may be also let out on a contract basis at a stipulated rate per ton to the foremen or a contractor, who in turn makes his own bargain with the laborers. No attempt should be made to materially lower the actual cost of handling. The company's advantage consists in securing fewer and better men, and, in eliminating the labor agitator or disturber. It also results in quick handling of freight as the men will hurry or work overtime when necessary. In practice, it has been found that the cost per ton for handling freight is quite alike in amount to the rate of wages figured on the hourly basis.

Mechanical handling in freight houses. — The difficulty in the use of mechanical conveying devices in freight houses is not in devising appliances, but in their adaption : 1° when the sizes and weights of packages are of infinite variety, and 2° where the packages are received and delivered at numerous points. In other words the variety of packages and net work of movement in the average freight house makes an adequate installation of mechanical handling very difficult.

Where there is a fixed point or points for loading and unloading, and a reasonable uniformity in the size and weight of the packages to be handled, as in a warehouse or industrial plant, the problem is simple and the question resolves itself into one of choosing the most suitable of the several very efficient systems on the market, but the freight house problem is complicated by the demand of great flexibility.

Trolley, telpher and belt conveying systems have all been considered and to some extent tried, but have never been entirely successful for mixed freight handling, as their fixed routes could not be adapted to actual conditions.

Hand trucking, while slow and costly, meets all the conditions of flexibility,

and it is along these lines, with the replacement of man power by mechanical power, that the greatest advance has been made.

In large well-managed freight houses, motor trucks are rapidly displacing the hand trucks, and the most economical method is the use of a motor car as tractor hauling after it a train of 7 to 10, four or six wheeled trailer trucks. This system has the advantage of flexibility of movement with no fixed routes, as in the case of carrier or telpher systems, involves no structural changes to the house and entails comparatively small investment.

Where average trucking distance is in excess of 100 feet, there is decided economy in the introduction of tractors and trailers if the amount of business justifies the expenditure. In many instances their introduction in large freight houses has resulted in a saving of from 30 to 50 % in the cost of trucking.

The use of trailers, instead of motor cars operated as single independent units where sufficient equipment of trucks is provided gives greater flexibility and facility of distribution. The tractor taking a train of loaded trucks drops them at destined car, or place in warehouse and collects empty trucks for delivery to loading points.

Where any considerable piling is to be done, inclined elevating conveyors or a portable trucking elevator worked by storage battery or direct electrical connection can be used profitably.

At transfer stations where the freight consists mainly of packages that are fairly uniform in size and shape, and the volume is considerable, movable platforms have been successful.

The rapidity of trucking with power trucks tends to speed up the work of loading, unloading and stowing freight.

The New York, New Haven & Hartford Railway, have installed a system of handling L. C. L. freight by tractor and trailer in their outbound houses at Boston, Mass., the outstanding feature being, that the haul rarely exceeds 100 feet.

The system is at present used in two of the largest of their five outbound houses, each of which is provided with 52 doors on the receiving or driveway side, and 20 doors on the loading or track side, so that freight unloaded is handled through the 20 rear doors.

Under this system cars for a certain destination are always spotted at the same location, and directly across the house from the doors assigned for the receipt of shipments for that particular destination, thus securing a direct haul, into proper car; thereby avoiding all confusion and congestion resulting from crossing traffic.

Prior to the installation of tractors and trailers, freight as received was dropped on the floor by teamsters, checked by receiving clerk and bill of lading signed. It was then necessary to move freight back into the house to await rechecking and loading, in order to keep doorways clear; this was done by doormen with hand trucks, then the loading into cars was done by trucking gang after rechecking of shipment against shipping order.

As two distinct operations were involved in this method and much time lost by having to move freight back to the centre of the house and also delay in delivery of shipping orders to billing department, it was decided to try the drop truck method.

Under this plan four wheel trucks were provided and placed at the receiving doorways, teamsters being required to unload direct to trucks thus keeping freight off

the house floor. Doormen kept a sufficient number of trucks at the doors, while a tally man checked the number of packages, chalked them with the outgoing car number and signed bill of loading, eliminating one check and one handling. Loaded trucks were then pushed into assigned car by laborers.

This latter system proved vastly superior to previous methods but it was still impossible especially in the late afternoon, when a heavy run of freight was offered to keep the floor free of freight, consequently it was decided to replace man power trucks with tractors and trailers, and these were placed in service September 1921.

Since the use of tractors and trailers it has been possible to keep the floor of the house free from freight and cost of handling has decreased from 67 cents to 50 cents per ton.

Because of the short haul and absence of turn around platforms on the farther side of outgoing cars, pushing rather than hauling is the prevailing method.

Although the tractor will turn in a car, the push method has been found expedient, as after pushing its load into car, it backs out and repeats, keeping busy all of the time in one part of the house or another, and stevedores unload the trailers and push them back into house. A driver and helper are on each tractor, the helper makes the hitches and steers the trailer when being pushed.

As an example of modern American practice in the design and operation of city freight terminals, a brief description is given of the New York Central Railway, new city terminal at Cleveland.

The local freight business having outgrown its facilities, the company in 1918 completed in a new location a modern comprehensive local freight terminal at a cost exceeding $4 000 000. The terminal is near the heart of the business district of the City, and comprises inbound and outbound freight houses with a capacity of 235 cars and team yards with tracks holding 550 cars.

The building layout consists of two separate and parallel houses, 1 262 feet long, the inbound 75 feet and the outbound 38 feet wide, the two being connected at the west end with a platform 50 feet wide. Above this connection is a building of two floors occupied by offices, this being carried over 296 feet of the outbound house in one story. The inbound house has two stories above the driveway level, and basement all used for freight handling and storage.

Adjoining the inbound house is a covered platform 12 ft. 3 in. wide, between which and the outbound house (which has no platform) are three island platforms, 16 ft. 6 in. wide, alternating with four pairs of tracks on 12 feet centres.

Hand operated bascule bridges 16 feet wide connect the platforms at the east end, and at two intermediate points. These bridges divide each track into nine car sections and one ten car section, making the total capacity of the eight tracks between the houses 224 cars. Eleven additional cars can be placed along the 24 × 300 feet uncovered platform for handling automobiles and ten more east of the island platforms for icing.

The framing of the building is steel with both interior and exterior walls of vitrified paving brick. This brick was considered necessary to stand the hard usage to which a freight house is subjected. It also gives to the exterior walls a strikingly pleasing appearance. All angles,. door posts, etc., are protected by steel guards.

The floors of platform and the first story are 1 1/8 inches carbolineum treated matched maple. In general, it is laid on a plank under floor bedded in a bituminous concrete.

Longitudinal panel spacing in both buildings is 21 feet to correspond to an assumed car length of 42 feet, steel side posts support the island platform covers and are spaced 42 feet centres.

Doors 9 × 9 feet are placed along the track side of inbound house in every second panel opposite the car door position. Along the track side of the outbound house, where there is no platform, doors 9 × 19 feet are spaced every second panel. The wide doors are used to eliminate the necessity for close spotting of cars. The doors along the team-side of both houses are 9 × 9 feet. All doors are of the rolling steel curtain type.

Seven electric elevators, one 9 × 22 feet 10 ton, five 8 1/2 × 11 feet 6 ton, and one 8 × 9 feet 5 ton, equipped with car gates and electrically operated landing gates, are installed in the inbound house. Doors are provided generally on opposite sides of shafts to avoid interference with in and out movement of trucks. The elevators are located with specific reference to the trucking bridges. Structural provision has been made for seven more elevators in the inbound house to be provided when the additional stories are added.

Twenty-four 6 × 8 feet 6 ton automatic dial platform scales are provided in the outbound house and six in the inbound house.

Automatic sprinklers are provided in the offices, and numerous fire hydrants, etc., with hose in the houses.

A private branch telephone exchange gives automatic inter-communicating service to nearly 100 points in the offices, houses, on platforms and in the yards.

The offices with which the public deal have been conveniently located with sub-offices at convenient points in the plant.

A pneumatic tube installation between the outbound checkers booth, foreman's offices and proper department of main office permits more rapid transmission of bills than the usual messenger service.

A cold room for protecting perishable freight held for shipment or delivery is located on the first floor of the inbound house, the temperature of which is regulated by an eight ton refrigeration plant, and above this is an ice storage room containing ice, primarily for icing cars.

The length of the house was determined by the possibilities of the ground and the conclusion that this was the greatest length that could be efficiently operated. A prime necessity of economical and rapid freight handling in a big terminal is the ability to switch cars in and out promptly, this terminal has been designed with special reference to this feature, the track arrangement permitting the house and team yards to be switched at the same time without interference.

Tracks are on the street level, with the floors of houses, and platforms at the height of car and auto truck platforms. Platforms are well lighted artificially and plug boxes for extension cords are placed at each car for use when needed. On each platform at each bridge is displayed a prominent yellow marker light to indicate to employees the location of the nearest bridge. Blue lights throughout indicate fire protection equipment; the bascule bridges are automatically signalled with red and green lights.

Team yard. — Separate outbound and inbound team yards are provided, the

tracks having an average capacity of 20 cars, permitting easy switching. The team driveways have a clear width of 40 feet, permitting the largest truck to stand backed up without blocking the driveway. Brick team track offices 20 × 35 feet in plan have been provided in both the outbound and inbound yards. A 9 × 20 feet 20 ton auto scale is to be installed in connection with both yards. A gantry crane electrically operated with a 25 ton main hoist, and a 5 ton auxiliary is installed.

Three plans of this terminal are attached (figs. 1 to 3), the first being a general plan of the houses and team track, the second a first floor plan of the freight house proper, and the third a cross section through the freight house looking towards the head house.

Operation. — The operation naturally divides itself into two classifications :

1° Outbound freight received for shipment;

2° Inbound freight shipped in for local delivery.

Each of these, as they differ materially will be treated separately. There is also a small amount of transfer freight handled from inbound cars to outbound cars for forwarding.

Staff. — The staff consists of a general foreman and assistant foreman for each shed, with route clerks, checkers loaders, tractor operators, freight handlers and stowers for the outbound shed and delivery men, tally men, pilers, callers, freight handlers, etc., for the inbound shed.

Outbound. — A driver with freight for shipment goes with his shipping bill first to any one of the three route clerks, located in special booths at the end and centre of the house. These clerks mark the shipping bill with the route and spot number of cars in which freight will be shipped, and indicate to teamster the door of freight house at which it is to be delivered. These clerks are experts, and the handling of routing by them relieves the receiving clerk, prevents errors and saves time as the teamster knows exactly where to deliver his freight.

The checker and gang receiving freight generally load it direct from wagon to four wheel trailers, chalk on it the car spot number, weigh it on automatic dial scale adjacent to the door and shove trailers out into aisle where they are grouped by another man in car and platform order to be picked up by a tractor. The tractors, moving westerly in the house, pick up « trains » arranged in car order for ~~one~~ platform, move around the end of the house or over a trucking bridge to the designated platform and drop the trailers at the proper car. Moving on, they pick up empty trailers, returning them to the various doors for loading. The crew of the tractor consists of a motor man and brakeman, who looks after the coupling and uncoupling of the trailer. This extra man has been found to speed up operations.

All the stowers on a platform work in one gang under the supervision of a head stower, who is responsible for the proper loading of cars. By means of the telephone installation, the head stower promptly notifies the foreman's office of fully loaded cars which in turn notifies route clerks and checkers, thus avoiding back hauling of freight and consequent confusion.

Checkers, as soon as a loaded truck has been taken off the house floor by the

Fig. 1. — New York Central Railroad. — Track layout for freight houses and team yards. — Cleveland (Ohio). — Not to scale.

A = Outbound team yard — B = Inbound team yard. — X = Auto receiving platform.

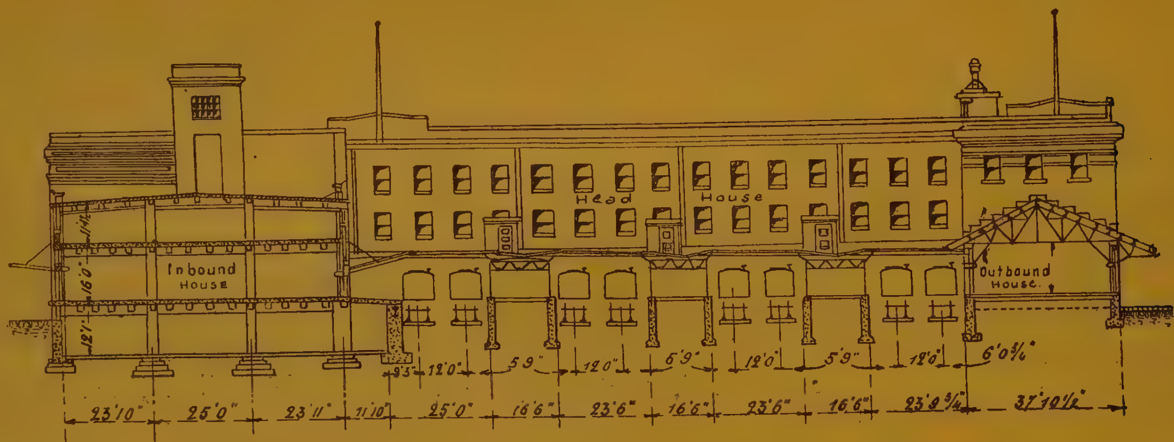


Fig. 3. — New York Central Railroad. — Cross section through freight house; looking towards head house, Cleveland (Ohio). — Not to scale.

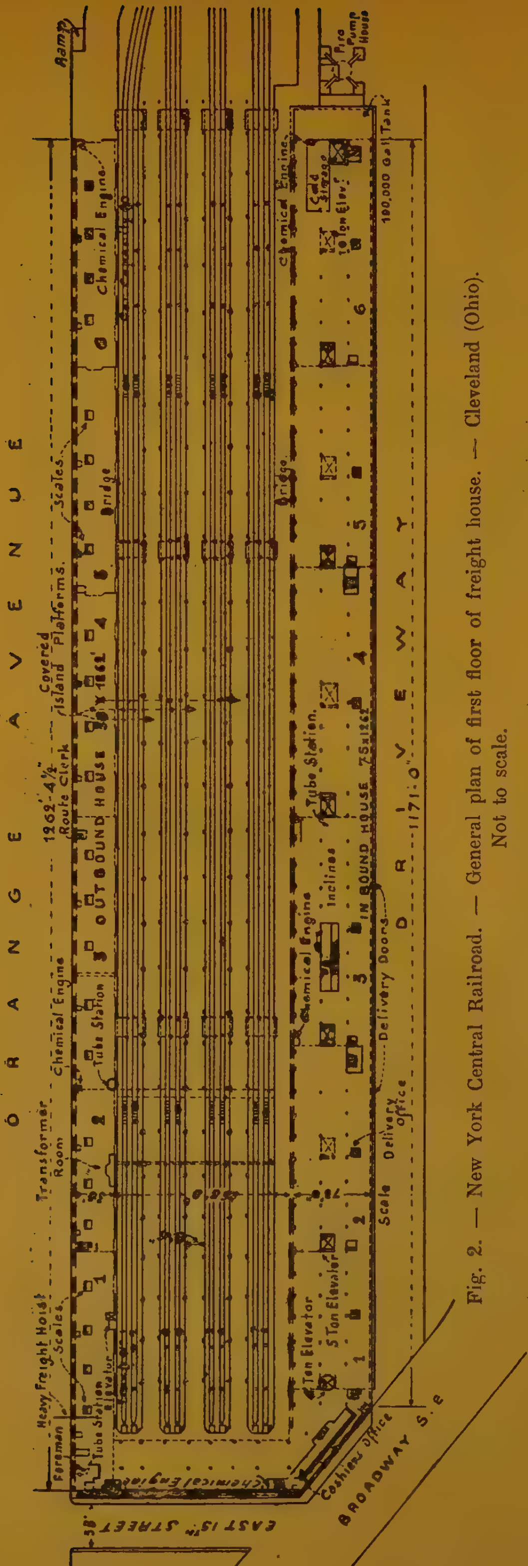


Fig. 2. — New York Central Railroad. — General plan of first floor of freight house. — Cleveland (Ohio). Not to scale.

tractor, « shoots » his bills by pneumatic tubes to the billing department. This results in a continuous flow of bills from checkers to proper departments and insures bills being prepared and ready to send with cars shortly after the closing of the house for the day.

Car « spots are numbered systematically, the first number denotes the track and the last two the position on the track, as for instance 601 to 628 for the 28 cars on track 6. Permanent sign boards on the platform mark the position of the cars.

The trailers are of reinforced wooden construction, 36 × 75 inches, platform 20 inches off the ground. The main wheels are 18 inches and fitted with roller bearings. For heavy freight, notably oil and paint in barrels, special all steel underslung trucks with platforms 8 3/4 inches from the floor are provided. Special dollies and equipment have been provided for special classes of freight. A hoist is provided to handle heavy freight from auto trucks to dollies or floor of house. This consists of a suspended I-beam runway extending 8 feet over the driveway and back 16 feet into the house. On this are operated two three-ton geared trolley hoists, giving a combined capacity of 6 tons.

The tractors used are three wheeled storage battery type developing a drawn bar pull of 450 lb. and with a load of 3 or 4 tons, speeds of 5 to 6 miles an hour are used. 11 tons are regularly pulled but at reduced speed. This type of tractor, on account of its short turning radius has been found very suitable.

Inbound freight. — The inbound house is divided into six sections by five walls, each section is in charge of a foreman with a clerk and two pilers. Sec-

tions 1 to 4 are allotted to freight for firms whose business is regularly large enough to justify such assignment. These spaces are permanently marked by appropriate signs. Sections 5 and 6 are arranged alphabetically for smaller and miscellaneous consignees. Freight for a given shipper thus goes always to a given destination. Freight arrives in many and various shipments, and as it is impracticable to place these in any predetermined order, long hauls are the rule. Under this condition hand trucking was very expensive and tractors and trailers have been substituted with markedly good results.

Trailers are loaded to capacity at the cars with freight for one consignee if possible, otherwise for one section. They are put in trains, pulled into house by tractor and dropped off at main aisle nearest the proper pile for unloading.

When the size of a shipment or several shipments for one consignee justifies it, freight is unloaded from trailers to 42 × 60 inch lift platforms, which, when delivery is to be made, are taken by special lift trucks to freight house door. The use of these platforms and lift trucks saves handling and results in considerable economy.

Special problems. — As mentioned above, special problems and difficulties arise when it becomes necessary to establish substations for the collection and distribution of freight in the same city, involving as it must, transfer of freight to different cars at some central point in order that it may be properly loaded for the road haul or sorted for delivery. The question is often further complicated by the necessity of transferring freight to connecting line stations. The problem has been solved in an interesting manner in Cincinnati. A large percentage of the tonnage of L. C. L. freight coming into Cincinnati is for transfer to connecting lines or to substations for delivery. Prior to 1919 this business was handled by horse-drawn drays, ordinary motor trucks and trap cars, that is, ordinary railway freight cars used for the transfer of L. C. L. freight between different railways in the same city. This meant in the case of freight moved by horse-drawn or motor vehicles unloading from car to floor of inbound house, loading in vehicle, unloading to outbound house and reloading into cars; in the case of trap cars, unloading from road car into trap car, switching of trap car, and reloading from trap to road car. The average time of transfer was 2.6 days and the cost was high.

In 1917 the Cleveland Cincinnati, Chicago & St. Louis Railway made a test installation between its main and five substations of a system of motor truck transportation utilizing detachable bodies, and in 1919, after a study by other roads, the system was installed to serve all main and substations in the city.

Incoming freight destined for a connecting line or substation is unloaded directly to an empty demountable truck body carded for that particular connection or substation; when fully loaded body is transferred to truck by means of an overhead trolley and taken to destination; at destination body is lifted from truck and deposited on floor of outbound house and contents loaded directly to cars.

The trucks operate under telephone orders of a central despatcher who is kept constantly advised of the loaded bodies available for transfer. In this way, empty movement of trucks is kept at a minimum.

The apparatus for handling the bodies

at the freight station consist of an electric hoist travelling on overhead rails. The hoists pick the body from the truck and move along the overhead rails into the freight house (with the body suspended), and when in position it is deposited on the floor. At comparatively small expense, existing structures were adapted to the installation.

The average cost of transferring freight prior to this installation was $1.72 per ton, compared with the present cost of $1,33 per ton which cost makes allowance for interest and depreciation on capital invested in motor trucks, demountable bodies and overhead structures as well as operating cost. Besides a saving of 39 cents per ton, there is a considerable reduction in the handling cost in both the outbound and inbound sheds, as well as a reduction in average time from 52 to 10 hours. The capacity of the freight houses and tracks has also been increased by the rapid movement of freight and the making of the trackage formerly occupied by trap cars available for road cars.

An extension of the same idea has recently been put into effect by the New York Central Lines in its services between Chicago and Cleveland for the purpose of developing the transportation advantages to be derived from the handling of less than carload merchandise freight in containers.

The containers are of two sizes, inside length 14 ft. 2 in. width 7 ft. 1 1/2 in., height 7 ft. 7 3/8 in., capacity 7 000 lb. and inside length 6 ft. 7 in. width 7 ft. 1 1/2 in., height 7 ft. 7 3/8 in., capacity 3 500 lb. They are of steel frame construction and at each corner have a heavy hook for handling between truck and car. Special railway cars have been designed for the transporting of these containers, each car carrying three of the large containers or any combination in which each large container is replaced by two small ones. Bodies are loaded by merchant at warehouses, transported by truck to railway yard, transferred to specially designed car by crane, rail hauled, unloaded by crane to motor truck and hauled to consignee. For trial, existing gantry cranes and team track facilities have been used, but an extension of the system would require special facilities or at least a rearrangement.

A summary of the advantages to be had by the use of the container is as follows :

a) It will furnish a means of expediting delivery of less than carload lots of commodities by eliminating the time and expense of rehandling, checking and trucking;

b) It will eliminate costly crating and packing;

c) The immediate loading and unloading of containers at the terminal point eliminates the item of demurrage, at the same time promptly releasing rolling stock, clearing the yard of cars and reducing congestion;

d) It will eliminate the piecemeal loading of cars at railway sidings in exposure to all kinds of weather;

e) It will tend to keep the car moving at all times, making possible double the mileage as made by an ordinary piece of rolling stock;

f) Containers are fire-proof, weather-proof, and burglar-proof, in that they cannot be opened while on the car or while being transferred by handling device, to and from car.

English practice. — In the treatment so far given the subject, only American methods and practice have been dealt with. English transportation practice differs in many important details from

American, and these differences necessitate separate treatment of the terminal problem.

The most striking dissimilarity as seen in the freight itself and in the design and capacity of the freight cars. It has been said that the freight traffic in England is retail in character, while that of America is wholesale.

The English merchant because of his nearness to the sources of supply and the expeditious service of the railways is not accustomed to carry large stocks of goods. The services of the railways are such that goods ordered one day, are delivered at his door the next morning. They find they can rely upon railways for good service which equals that of express companies in America, and this has the effect of forcing the railways to handle a large volume of small packages and a relatively small number of carload shipments.

The second important difference between the British and American freight service lies in the British practice of collecting and delivering freight. In Great Britain there are no express companies as known in America, and instead the horse-driven or motor vans of the railway companies call at the consignor's warehouse for the freight to be shipped, and at destination, deliver it at the door of the consignee. The freight rates include the cartage at both points, but the shipper has the option of doing his own carting and paying a lower freight rate. Generally speaking, however, the railways do practically all of the cartage, except in the case of certain bulky or dead freight.

In the collection of freight to be despatched in trains, the British roads follow methods quite similar to those of the express companies of America. Each railway has a distinctive card which it distributes to shippers and which is displayed when freight is to be called for by the railway vans. Or the shipper may telephone or otherwise request the railway to send its van. When freight is offered for shipment, the consignors make out the consignment note (corresponding to American shipping order) and when it is accepted by the driver of the van the responsibility of the railway begins. The freight is checked by the driver against the consignment note; it is again checked when unloaded from the van to the platform at the freight station, where the goods are weighed and finally checked once more when loaded from the platform into the cars.

The freight « wagon » of Great Britain runs on four wheels (two axles) and the great majority have a capacity of 8 to 10 tons. Larger cars are used, many of 20 tons, and a few with a capacity of 30 tons. The small car is the result and not the cause of the retail character of the freight service. Even if larger cars were available and would clear structures, it would be a long time before their capacity could be utilised, and the road to begin a campaign of educating shippers to the economic necessity of holding cars for full loads would suffer in competition with the road adhering to the small cars and sending it forward on schedule whether filled or not. As a matter of fact, it seems impossible now to get a full load in their eight ton cars; the average car load is small, usually about 2 or 3 tons, and efforts to obtain more loading would adversely affect the regularity and speed of trains the two factors in which competition is keenest. Such efforts would also reduce the number of through cars to small branch line points or junctions, increase the percentage of shipments transferred and other-

wise tend to curtail privileges of long standing, brought about by competition in service.

It may be argued that while the reason just mentioned applies to merchandise freight it has not the same force in its application to the transportation of dead freight, such as coal. But here again, there are retail influences which restrict the carload. According to an official statement made a few years ago the average consignment of coal is 17.5 tons. Eight percent of the coal shipments are less than 20 tons, and many are as small as 2 tons. These instances will show that in order to make the larger car profitable, it would be necessary first to revolutionize the British system of sales and distribution, and until something of that nature is accomplished the 8 and 10 ton cars will continue in use. Some of the companies are experimenting with larger cars, but in using them another practical difficulty is encountered, in adapting the scales, chutes, and other loading facilities, as well as trestles and unloading arrangements at destination. These were all designed for a smaller car and will not permit the use of the larger car without extensive alteration.

The following description of a London Terminal is taken as typical of English practice and shows how the special problem of an exceeding dense traffic in a limited space is handled. The terminal described is that of the London & North-western Railway at Broad Street. The material is taken from Findlays « The working and management of an English Railway ».

The Broad Street Station is the City depot and is right in the heart of London. Land being extremely valuable, the line is carried during part of its course by means of bridges and viaducts at high elevation, in some cases over the tops of houses, and thus reaches its terminus at a point considerably above the level of surrounding thoroughfares.

The passenger station having been built on arches, the railway took advantage of the situation to provide themselves with an extensive freight station in the busiest part of the city without the enormous expense of taking land for that purpose. The freight traffic is handled in the arches under the passenger station, freight cars being moved on elevators from one level to the other. All along the front of these arches fourteen in number, and including some space beyond them which has been covered in, an unloading platform has been erected. Each arch measures 340 feet in length and 32 feet in width. The length of the platform is 430 feet and its width 45 feet. From the main unloading platform and at right angles to it are narrow platforms 12 × 240 feet, with a track on each side, extending through each arch. These tracks are connected with a cross line by small turntables, by means of which cars are turned and taken to elevators.

On the farther side of the arches some additional space has been acquired on the street level to form an open freight yard, on one portion of which a lofty warehouse has been erected for the storage of goods awaiting delivery or to be held in transit.

Traffic arriving from the country for delivery in London is called « up traffic ». That sent from London is known as « down traffic ». The « up traffic » consists largely of provisions for supplying the early markets with fish, meat, poultry, butter, eggs, and other perishable commodities which have to be delivered as early as 4 a. m., also general merchandise purchased from manufactu-

rers in the province the previous day and expected to be in the city warehouses by 9 a. m. This part of the business is conducted in the warehouse, the ground floor of which is staged so as to form a platform upon which the goods can be sorted and transferred from the cars to the street vans. This platform is open on both sides so that vans may be backed up to it on one side and the freight cars run in on the track on the other side. The invoices (waybills) are passed through the delivery office where each is entered in a book, stamped with the progressive number, timed as to arrival, checked as to the correctness of rates and extensions and is then passed to a marking clerk who marks against each entry on the invoice the position of the freight on the platform.

The whole of London is marked out into districts, each of which is designated by a letter and number, and the platform is divided into sections to correspond with these districts. When the invoice is marked by the marking clerk, it is passed to other clerks who extract from it and enter on the carman's delivery sheet and finally taken in the vans to their destination. The « down » or outward traffic is handled in the arches. During the day, the tracks alongside the platform are filled with empty cars into which the goods are loaded as they come in during the afternoon and evening. As fast as the « up » goods are unloaded at the warehouse platform the empty cars are transferred to the « down » arches. As the loaded vans come in at the gates they are placed in position for unloading on the platform. The shipping orders relating to each load are checked against the freight as it is unloaded and the freight is weighed on weighing machines stationed at regular intervals along the platform. Each arch is reserved for goods for certain stations or districts and as the freight is unloaded from the van, the checker directs the truckers where the freight should be trucked. From the platform the goods, when deposited in the proper location by the trucker, are placed in the car by the loading gang, which consists of a checker, a loader, a caller-off, and two porters. When the goods are in the car, the consignment notes are taken to the shipping office and from them the invoices are prepared. The freight cars, when loaded (sheeted with tarpaulin covers), and marked, are run out at the further end of the arches by means of ropes attached to hydraulic capstans turned on turntables and elevated on hydraulic lifts to the upper level, where in a group of ten long sidings and still by the aid of hydraulic capstans they are marshalled into trains and despatched. The process of marshalling is facilitated by arranging the cars in the arches in train order. In some cases the vans are driven alongside the cars and the freight unloaded directly from van to car.

Private sidings.

Private sidings are those built off the railway company's own property for the exclusive use and convenience of one particular firm or company. Their arrangement presents no special difficulty, and they will be very briefly treated.

Their location is usually governed by the wishes of the company they are to serve and the convenience of the railway company.

Almost universally they are installed at the expense of the applicant who is required to deposit the estimated cost before work is commenced.

The first placing of cars on the siding is usually done by the Railway Company free of charge while subsequent or inter-plant switching is charged for at cost.

The arrangement for loading and unloading cars are matters for the industry, the only concern of the railway being to see that it is done as quickly as possible and that as heavy a load as possible is placed in the cars. These objects can be obtained only by personal appeal to the shippers and possibly in the case of the worst offenders by the placing of an embargo.

Water Terminals.

The conditions surrounding the transfer of freight between water and rail, or rail and water carriage, differ materially from those at strictly rail terminals, and call for radically different facilities and methods of operation.

The necessary facilities for a complete water terminal are :

1° General yard;

2° Lighterage piers, covered or open;

3° Steam ship piers :

a) Covered piers for package freight;

b) Open piers for bulk or coarse freight;

4° Grain elevators;

5° Coal piers :

a) Outbound;

b) Inbound.

1° *General yard.* — The requirements of a general yard at a water terminal do not differ materially from those of an inland terminal. It should have a receiving, classification, and forwarding yard for outbound freight, and a classification and departure yard for inbound freight, together with the necessary engine facilities, etc. It should be arranged for the maximum ease of movement, advantage being taken of gravity switching to as large an extent as possible.

2° *Lighterage piers.* — Lighterage piers are provided for the transfer of freight from cars to small harbor boats called lighters either as a means of transfer between two terminals in the same harbor or between piers and ocean going ships when, on account of expense in construction, it is impossible to provide wharfage for the larger vessels. The points to be considered in their construction, equipment and operation are not essentially different, except as regards size, from those to be considered in the design of steamship piers and separate treatment will not be given.

3° *Steamship piers, general freight.* — The purpose of a steamship pier is two-fold, the first being to provide safe shelter to a ship while loading and unloading, and second, to afford an economical means of transfer of freight between land and water carriage. Only the second requirement will be discussed.

The length of the pier should be such as to accommodate either one or two ships of the size ordinarily sailing from the port. Piers for one ship will range from 600 to 800 feet in length and for double from 1 200 to 1 400 feet. A very good arrangement is to place the sheds for package freight on the inner end of a double pier, next to the bulk head, and reserve the outer end for open pier, on which to handle coarse materials.

The water frontage of a harbor is usually limited, and it is important that the space be used to provide as many piers as possible. For this reason they should be made as narrow as possible. On the other hand the conditions of ocean

shipment demand that ample space be provided for unloading a vessel without the delay incident to car supply and that the outgoing cargo be assembled prior to the berthing of ships to avoid delays in loading.

These requirements call for a certain minimum width of pier and transit shed depending on the size of the vessel. The sheds should be of sufficient width to accommodate approximately the total bulk of cargo in a length the same as the vessel itself. Two-storied sheds are preferable, both from a working viewpoint and as providing storage for both outgoing and incoming freight without undue width.

For piers designed long enough to dock two ships, the width must be greater to allow for through tracks serving the outer end.

Cargoes in modern ships use from 10 to 15 tons per foot of length, making the requirements as to width, 80 to 120 feet on each side of shed, and total width allowing for tracks of from 200 to 300 feet.

When it is considered that the value of storage space in cars, taking value of car, value of land and value of tracks is from $8.00 to $10.00 per square foot, and the value in pier sheds is one-half to one-third of this, the advisability of providing proper pier storage for outbound freight is seen.

The width of slips between piers is controlled by the necessity of free movement in and out of vessels. For piers of single ships length, the slip should provide room for a ship and coal barge lying abreast at each pier without crowding, and for one of two unit lengths enough extra width should be allowed to permit a vessel to move in and out.

For ocean piers the slips of one unit length should be at least 300 feet and for two unit lenghts 350 feet in width.

Ample trackage should be provided for the rapid transfer of freight, either directly between vessels and cars, or between transit area and cars. The first purpose is served by marginal tracks placed between the shed and edge of the pier. For short piers one track on each side is sufficient, but for longer piers two tracks per side should be provided and frequent crossovers arranged so that cars being loaded or unloaded at the inner end need not be disturbed by switching to the outer end. Marginal tracks are best at floor level.

For transfer between transit area and cars, depressed tracks in the centre of the shed are most convenient. For short sheds a double track serves, but for long sheds at least three tracks with proper crossovers should be built.

The depression of the centre tracks should be sufficient to bring the car floor level with the main floor of the shed.

When shed is of more than one storey, at least one track on the upper storey is a great convenience and should be provided where possible.

The mechanical equipment of a pier of two or more stories, handling package freight, may be divided according to the work which is to be done, into four classes;

1° Means of handling goods to and from ships;

2° Means for handling goods from place to place on the same floor;

3° Means of handling goods between different floors;

4° Means of piling or tiering freight for storage.

1° The most important in the first class is the ships own gear, but this is not sufficient to work all hatches at the same

time, and for rapid work auxiliary means must be provided. The simplest method is by means of cargo masts as used largely in the Port of New York, Masts, extending some 70 feet above the pier deck and spaced 20 feet centres are erected in line with the outer walls of the pier sheds, guyed back, and connected together at top by steel girders. To these girders, tackle is attached and goods hoisted and swung over ship's side, either by means of ship's winches, or winches located in the freight house. More elaborate and more expensive in first cost are portal cranes, which move along the side of the pier.

2° As in the handling of freight in freight houses, the most efficient method yet evolved is the motor tractor drawing a train of trailers. Where it is necessary or convenient to run the trailers on the ship a « gang plank booster » saves labor. This is a sprocket chain mechanically actuated running in a trough on the gang plank. The sprockets are so arranged as to engage a lug on the truck and carry it up the gang plank. The chain should be placed on one side so as not to interfere with the truckers returning.

3° The most convenient and efficient way of handling between floors for general package freight are power operated platform elevators, although where there is uniformity in the size of packages, escalators for elevating and chutes for lowering may be used to advantage.

Chutes from the second stories of pier sheds direct to cardoors on lower floors are good if sufficient quantities of flour or other commodities of similar nature are to be handled. Chutes may also be used for loading direct to boats.

4° It is important in transit sheds that space be utilized to the greatest possible extent. This means the piling of freight and it is well-known that the cost of handling mounts rapidly where packages have to be piled higher than a man can conveniently reach. To meet this problem portable inclined conveyors and elevating platforms have been used with marked success. The inclined conveyor is suitable for piling small bundles and boxes and the elevating platform for heavier articles. A type in use at Portland, Ore., will pile bales weighing 2 000 lb. three tiers high.

At a port doing a general import or export business, at least one open pier is necessary for the handling of coarse freight, such as lumber, structural steel, etc. It should be long enough to afford berthing space for the vessels which use it, and wide enough to afford ample storage for both inbound and outbound cargoes. The mechanical equipment will vary according to the class of material to be handled, ranging from piers without equipment and depending entirely on ships tackle for loading, to those furnished with gantry cranes, spanning the whole width.

Of these the bridge type with locomotive crane operating on rails overhead is to be preferred to the under-slung type. In addition, it is often of advantage to install a stationary crane or derrick of capacity up to 100 tons for handling very heavy articles. This should be of the revolving style so that certain articles can be unloaded and stored. The open pier may be also used to advantage in unloading and loading directly from box cars.

Where space on pier is not sufficient for proper storage, warehouses are provided behind the bulkhead for goods awaiting shipment.

The means of transfer from these warehouses to transit sheds on piers, varies, but the one offering the most advantages

is by tractors and trailers, a passage generally being provided from the second story of the transit shed to the second story of the warehouse and in modern installations supplemented by ample elevator service.

If the freight to be handled is uniform in size and weight, a system of belt conveyors from warehouse to ships side may be used. The belt conveyor has been used with success for the handling of coffee in sacks. The sacks are brought from warehouses set 360 feet from the pier, and loaded at the rate of 2 000 two hundred pound bags per hour. The conveyors extend in tunnels longitudinally of the warehouse, deliver to cross conveyors which extend to conveyors on brackets outside the sheds; these deliver in turn to conveyors on movable bridges extending over the side of the ship and delivering to the ships deck, from where the coffee is run by chutes to the hold. The only labor required is a few men at the transfer point to straighten the sacks as they pass.

Grain elevators. — With the exception of coal, the greatest advance made in the mechanical bulk handling of any commodity has been in the transportation of grain. It is handled mechanically from the time it leaves the farmers wagon at a wayside station until its form is finally changed in the mill. This has been due to the enormous quantity to be handled, and to its flowing qualities.

Throughout the grain producing districts, every wayside station has its grain elevator for storage and trans-shipment.

The producer drives his wagon loaded with grain into the elevator and dumps it into receiving bins; from the receiving bin it is elevated by bucket hoists or endless chain bucket conveyors to storage bins, from whence it is chuted by gravity to cars. These local elevators have facilities for weighing the grain as delivered, and also for drying and cleaning it if necessary. Their capacity ranges from 2 000 to 10 000 bushels depending upon the importance of the shipping point.

On the arrival of the car at a terminal or transfer point, it is run into a shed and unloaded into a depressed bin. As grain is almost invariably shipped in box cars, the unloading process has been one of the controlling features in the speed of operation. In the older elevators, the grain door is removed by hand; a certain amount of the grain flows out by gravity and the remainder is either shovelled out or removed by large scoops operated by block and tackle and guided by hand. In the more modern elevators box car dumpers are used.

The operator, by means of a car puller, places the car on the platform where it is secured by means of electrically operated end and side clamps. As soon as secured, the grain door opener comes into operation, pushing in and raising the door in one movement (the outer car door having been previously opened). When the grain door has been fully displaced, the platform, with car attached, is titled sideways 30° and rocked 45° longitudinally, first in one direction, then in the other, then back to level, when, all grain having been dumped, clamps are released and empty car displaced by the next loaded one.

From the time the first motor operating the clamps is started until the car is again ready to move, the whole process is automatic, the completion of one operation starting the motor controlling the following. By means of this device, one man can empty cars at the rate of eight per hour.

As the grain is unloaded into the re-

ceiving hopper, it is elevated to the top of the house and conveyed by belt conveyors to the bin in which it is to be stored.

When the time for reshipment arrives, the grain is run from the bottom of the bins by belt conveyors to elevator, elevated to top of house and chuted directly into cars or run by belt conveyors operating in galleries along the pier and chuted into the holds of vessels.

At points where grain is received in boats and is to be stored or transferred to cars, what are known as marine towers are provided. These towers are generally in the neighbourhood of 150 feet high, are built of structural steel and operate up and down in front of the elevator under their own power. In connection with the marine towers are marine legs enclosing bucket conveyors which are lowered into the holds of vessels, pick up the grain, transfer it to the marine tower which in turn elevates it to the top of the bins.

The practice is to provide in connection with grain elevators, reinforced cylindrical concrete storage bins approximately 25 feet in diameter and 100 feet high.

Facilities for drying, cleaning and grading, in addition to those for weighing are provided.

Ample track capacity for receiving, storing and handling both, loaded and empty cars should be provided.

Coal piers. — Coal piers are divided naturally into two classes; first those at which coal is transferred from cars to boats, and second, those at which the transfer is from boats to cars. The two processes differ widely and require plants of altogether different characteristics.

The first, or from car to boat, is a comparatively simple process, and with proper facilities, the cost per ton can be reduced to a fraction of a cent. The methods of handling vary from simple elevated trestles, on which cars are run and dumped through a chute to boats, to very elaborate plants at which cars are elevated and dumped by machinery, into bins.

The extent of the plant and elaborateness of the equipment depends on whether the volume of the business justifies the capital expenditure to insure a low operating cost.

The extent and variety of mechanical equipment that has been developed for this trade can best be shown by short descriptions of some of the recently constructed plants of American railways on the Atlantic seaboard.

As typical plants, differing essentially in one or more features of design, the Central Railway of New Jersey at Jersey City, the Baltimore & Ohio at Curtis Bay, and the Pennsylvania Railway at Canton have been taken.

Central Railway of New Jersey at Jersey City. — The plant is approached through a series of yards a mile in length, consisting of a receiving and advance yard which serves two gravity yards each of which serves independently a car dumping unit. There is also a yard for the assembling of empty cars.

The pier, as at present constructed, is 970 feet long, but it is intended to extend it to 1 585 feet, and provide 21 pairs of circular reinforced concrete tug coaling pockets.

The normal width of pier is 126 feet; tapering to 66 feet near the outer end, and flaring to 184 feet near the bulkhead to facilitate track layout. It is built on creosoted piling and has a reinforced concrete deck with heavy concrete foundations for dumpers, etc.

Two dumpers are provided, one on the north side 300 feet from the bulkhead and one on the south side some 300 feet farther out.

As the track layout and dumpers are practically identical, only the one on the north will be described.

Track layout. — The grade from the advance yard to the bulkhead line is 1 % down, allowing cars from the advance yard to approach by gravity; from there to the floor of the car dumper, the grade is 12 % up, cars being elevated by cables. The floor of the car dumper is level, and is followed by a down grade of 11 %, and a « kick back » grade of 18 % on which the movement of cars is reversed to the return track with a down grade towards the bulkhead of 1.5 %.

The car dumper consists of a steel tower in which is located the cradle where the car is clamped, elevated and dumped. The cradle is designed to handle various sizes and types of coal cars of width up to 11 ft. 6 in.; heights of 6 ft. 6 in. to 13 feet and length over couplers of 54 ft. 4 1/2 in. with a maximum gross weight of 280 000 lb., including tare of car. Steam power is used to operate the cradle and haulage car, and electric power to operate the pan, chute, screening conveyor and boat haulage.

The cars, after coming on the cradle are elevated and dumped into a steel pan of 100 tons capacity, and from this pan coal is loaded into boats by means of telescopic chutes. For barge loading, the pan may be placed in a lower position, but for very high steamers its position will require, that the car be elevated as much as 30 feet before it is turned over. Provision is also made for raising and lowering the outer end of the pan to clear masts of vessels while being moved, and to change its inclination to the minimum degree for handling various grades of coal. To facilitate the unloading of the pan, elaborate provision is made for boat haulage by cables controlled by electric motors.

Operation. — After a car is released from either of the gravity yards by its rider (who remains with it until it is returned to the empty yard), it is located over the haulage pit by gravity, then pulled up the approach grade to the dumper by haulage car operated by steel cables; when the car reaches the platform of the cradle, it pushes the car which has just been dumped down the run-off grade. When delivered on the platform of the dumper, the car is first shifted horizontally until it is held between the wooden buffers on the sides, then lifted vertically until the clamps which hold it in place are actuated by a contact with them, the car and cradle are then raised and contents dumped into the pan. It is then brought back to its original position in the cradle, displaced by another car, started down the run-off grade, and returned by the « kick back » to the return track and by gravity to the empty yard.

The cars are pushed up the approach grades to the dumper by a machine known as a « barney ». This is a small specially constructed car hauled by cables attached to a hoisting engine. It runs on a depressed track between the main rails, and by means of a movable arm, which raises up and engages the car when the « barney » starts, pushes it up the incline. There is pit at the foot of the grade into which the « barney » drops while the coal car is being placed.

The capacity of the plant is 400 cars per day.

Baltimore and Ohio Plant at Curtis bay. — The railway at this point had two conditions to meet; it desired to load large ships quickly, and at the same time handle small shipments for local vessels of all types without interfering with the larger operation. The Company therefore decided on a system of belt conveyors, travelling towers, which the conveyors mount, and cross conveyors on the towers. With this system 7 000 tons of coal per hour can be handled.

A receiving yard is provided, and ahead this an advance yard with a thawing house. Cars are pushed over the hump from the receiving yard to the advance yard which is on a 1 % down grade, and from that point no locomotives are required except to remove cars from the empty yard. With brakes released, the cars run down to the foot of the incline where a « barney » hauls them up an 11 % grade to the car dumper, about 40 feet above the foot of the incline. After dumping, they run down a grade on the far side, up another steep grade where their movement is reversed, and back down a 1 % grade on a track passing outside the dumper to the « empty » yard.

Two separate and independent dumpers are installed, fed from the same yard and feeding the empty cars back to the same yard.

Each car dumper empties into a lowering bin, a hopper under which supplies three short feeder belts. Two of these from each dumper feed the main 60 inch loading belts, which pass the full length of the pier. The third delivers to another conveyor carried on an inclined bridge. The lower end of this bridge pivots at the discharge end of the short conveyor, while the support near the centre travels on the arc of a circular track, so that the conveyor can be discharged at any desired point, into what is called the balancing bin at the shore end of the pier. Thus, there are four 60 inch loading belts, and over them a large balancing bin, fed from two conveyors on two inclined rotating bridges. From the balancing bin and bed by it, run two more belt conveyors, one on either side of the main belts on the edge of the pier. These are 42 inches and are known as the trimming belts.

Corresponding to each of the main belts is a loading tower. These are similar, being travelling bridges spanning the main belts and carried on a track system between the loading and trimming belts. Each tower, however, takes coal from one belt only. An incline at the shore side of the tower takes the belt up and discharges it upon a cross conveyor or shuttle ram on the bridge, the empty main belt then doubles back and passes under the tower, out to the end of the pier and back to the dumper.

The cross conveyors on the tower have three kinds of motions. The belt can be run in either direction to load ships on either side; the conveyor frame can be moved longitudinally so that the belt will discharge 35 feet beyond the side of the pier and it can be raised and lowered within a range of 27 feet to conform to the height of the vessel, the incline of the main belt being altered accordingly.

In a similar manner, each trimming belt serves a trimming tower, there being one on a special track on each side of the pier. The belt passes up an incline on the tower and discharges into a hopper, which in turn feeds a conveyor on a swinging boom. The name of the trimming tower tells its purpose.

The object of the balancing bin is also implied in its name. Normally the bulk

of the coal is handled by the main loading belts. During the movement of a tower from one hatch to another, coal can be diverted to the 5 000 ton balancing bin and the dumping of the cars need not stop; conversely two of the main belts can be fed from the bin in case the car dumper is not working.

With 12 men one unit will load a 7 000 ton ship in 3 1/2 hours. This compares with 7 1/2 hours at the old trestle. More than one unit, however, can work on a ship as each tower has a range of the whole 700 feet pier except at the ends where the 35 feet width of each limits the travel.

Pennsylvania plant at Canton. — This plant combines car dumpers, four ton cable cars and travelling loaders on the pier. It is designed to serve vessels and barges of every sort in the coastwise trade.

The yard and car dumping arrangement is somewhat similar to that described in the Baltimore & Ohio system, except that it is on a smaller scale and only one car dumper is provided. The dumper hopper feeds into four ton cable cars travelling on an endless narrow gauge track. The cars are hauled up a 6.72 % grade to a high steel superstructure in the centre of the pier, they pass to the outer end of the pier back, and down an incline to the starting point. In transit they can be made to deliver their coal to any of the three travelling loaders that constitute the second distinctive feature of the system, or deliver it into any of the bunkers provided at the outer end of the pier on the south side.

The loaders are machines moving along the pier on a two rail track and carrying a hopper and chute delivering into the holds of the vessels.

There are two loaders on the north side and one on the south side, in addition to the weighing loader which travels along under the pier bunkers. The loaders are all of somewhat different design to suit different types of boats. Number 1 is the largest and intended to serve the largest class of vessels. It has a hopper of 40 tons capacity and is equipped with a pan conveyor and movable arm, so that the coal can be made to go either up or down as required. It has a reach up of 34 feet and will go over the side of the ship 56 feet above water level.

Numbers 2 and 3 have smaller hoppers and gravity chutes. Number 4 is the weighing loader. It receives its coal from the pier bunkers, of which there are 10 of 75 tons capacity each. This loader has a 10 ton hopper and is equipped with a conveyor.

The pier is 1 600 feet long and 66 feet wide. The present capacity of the plant is 1 500 tons per hour. By the addition of more cable cars, this can be doubled without changing any of the other units.

Transferring coal from boat to storage or cars. — The transferring from boats presents a harder problem but one which has been solved in an infinite variety of ways according to the local conditions, amount of capital available and expenditure justified to attain low operating costs.

Methods range from a simple derrick operating a clam shell bucket through a great variety of towers and bridges, to machines of the Hulatt type capable of handling 1 000 tons per hour.

The main principle of all these unloading devices is, however, the same. consisting of a mechanically operated digging bucket lowered into the hold of a ship,

hoisted out and swung or trolleyed to a hopper into which it dumps and from which cars are loaded.

The Hulatt unloader, which is the most modern development, consists essentially of two parallel girders at right angles to the length of the wharf and mounted on trucks. These girders support the trolley or carriage, which in turn carries the walking beam, the outer end of which supports a vertical leg provided at the lower end with a grab bucket. The bucket leg is suspended in a vertical position and the operator rides in it just over the bucket, and therefore goes into the boat with it at each trip, enabling him to see its workings and control its movements. By means of hoisting mechanism, the beam is made to oscillate up and down, carrying the bucket up over the hatch or to the bottom of the hold. When the bucket reaches the pile of coal in the boat, it is closed and filled, after which the leg is raised and trolleyed back over the hopper on the dock into which the contents are discharged.

From the hopper the coal is dumped into an auxiliary car, which in turn transfers the coal into ordinary open cars.

The bucket leg is mounted on rotating trunnions in the walking beam, so that it can revolve and reach out in all directions beneath the hatch. They have a capacity of from 10 to 15 tons and speeds of from 60 to 70 trips per hour are normal.

When operating in boats, specially designed for coal service, 90 to 97 % of the cargo can be unloaded without the help of trimmers.

The bucket operator controlls all movements of the machine, except movements from hatch to hatch, and the operation of the « bucket car » which movements are controlled by another man. Where large quantities of coal or ore have to be handled, no more economical or rapid method can be used than a battery of two or three of these unloaders working on one wharf.

APPENDIX.

Detailed list of questions relating to question X.

LIST OF QUESTIONS.

Team tracks.

1. — What length of team track is considered the most economical for operation and for convenience of shipper?

2. — What track centres are recommended :

a) Between pairs of tracks?
b) Between tracks for roadway?

3. — Do you favor stub end tracks or tracks connected at both ends?

4. — Are track scales provided?

If so where located with respect to general yard?

5. — Are wagon scales provided?

6. — Are any mechanical means of handling heavy freight provided?

If so describe briefly?

7. — Does the replacement of the horse-drawn vehicle by the motor truck necessitate any change in the general design of team delivery yards?

8. — What means are employed for showing the shipper the location of his car?

9. — Are any means beside the ordinary demurrage rules used to hasten the loading and unloading of cars?

10. — What practice as to time is followed in pulling the yard? *i.e.*, once or twice a day and at what hour?

11. — Are any type car pullers or mechanical means other than switching engines, used for spotting cars?

12. — Are any means such as elevated trestles or elevators provided by the railway for handling such bulk commodities as coal, stone or sand, if so, what type is used and on what basis are charges assessed?

13. — Are special yards provided for special commodities? or is the yard in which cars are placed controlled solely by the wishes of the shippers?

14. — In the design of new yards what is the relation between length of tracks provided and the daily tonnage to be handled?

15. — Are turntables or transfer tables in use to conserve space or facilitate pulling cars without disturbing other shippers?

Freight houses.

16. — What ratio does the floor space provided in :

a) Inbound houses;

b) Outbound houses, bear to the tonnage handled?

c) What average daily tonnage is necessary to make the provision of a separate inbound and outbound house necessary?

17. — What is the recommended width of :

a) Inbound house?

b) Outbound house?

18. — Are trucking platforms between pairs of tracks provided?

If so what width?

What has been found to be the advantage and disadvantages of trucking platforms?

19. — What is the relation between length of freight house and cost of operation?

20. — Are platforms outside the line of doors provided?

a) On team side?

b) On track side of house, if so, what width is recommended?

21. — What type of floor is used?

Has this been satisfactory?

Give recommendations.

22. — What slope of floor is allowed in the direction of heavy trucking?

23. — Describe system of handling in :

a) Inbound houses from time car is spotted to time freight is delivered to teams, including system of checking, trucking, storing and delivering?

b) Outbound houses from time freight is received from teamster at shed door to storage in car including checking upon receipt, inspection, trucking, weighing, checking into cars and storing?

24. — If possible give costs per ton for each class in question 23.

25. — *a*) Do you employ « piece work » in the trucking or loading of freight?

b) Has this system resulted in any reduction in cost of handling freight?

26. — Are cars spotted at outbound freight houses in the order of their delivery on the road so as to avoid unnecessary switching?

27 — In large freighthouses what system is used to notify shipper of arrival of freight and to give prompt information to telephone inquiries as to freight?

28. — Are teamsters required to deliver outbound freight at certain designated doors corresponding to destination of freight?

29. — In handling inbound freight what method of sorting freight for different shippers is used?

30. — At any of your terminals do you deliver freight from freighthouse to shipper or has each shipper to look over his own cartage? Give details of method.

31. — Are mechanical means for handling in freighthouses used?

If so describe the methods used and result in economy over hand trucking?

32. — Have you any freight houses of two or more floors?

Are there any advantages in multiple storied freight houses over single storied from an operating standpoint?

33. — Can you suggest any method, other than storage charges to expedite the removal of freight by shippers from sheds?

34. — What methods of fire protection are in use?

35. — What method of lighting?

Private sidings.

36. — At whose cost are private sidings constructed?

37. — If at the Railway Company's, is payment made in installments, or is a rental charged?

If a rental on what basis?

38. — Are cars placed by the railway on an interchange track and switching done by the shipper, or does the railway do the switching? If switching is done by railway, is an extra charge made?

Water terminals.

39. — *a*) For export trade, general package freight, what length of piers recommended?

b) What width of slip between pier?

c) What width of sheds?

40. — What track arrangement is recommended for a pier with berth at both sides, and long enough to accommodate two vessels?

41. — What width of platform is recommended outside of sheds on water side?

42. — Are all tracks depressed to bring car floor level with pier floor, or are only the centre tracks so treated?

43. — Does the erection of two or more storage freight houses effect the width of pier necessary?

44. — In two or more storied freight house, by what means is freight handled from floor to floor?

45. — What mechanical devices are in use for the transporting of freight from car to vessels and *vice versa*?

46. — Are the piers and terminal facilities owned by the railway, a private company or a commission? If the latter, does the railway company or the owner of the pier do the necessary switching?

47. — Do you recommend continuous wharves or piers? What special arrangement of track do you recommend for the different cases?

Note. — In answering questions, descriptions and plans of unusual layout or methods will be appreciated.

[656 .253 & 656 .259]

REPORT No. 3

(all countries, except France)

ON THE QUESTION OF LOCOMOTIVE CAB SIGNALS (SUBJECT XII FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION) (1),

By Faustino VILLA,

CHIEF ENGINEER OF THE CONSTRUCTION DEPARTMENT OF THE GENERAL MANAGEMENT OF THE ITALIAN STATE RAILWAYS.

Figs. 1 to 10, pp. 826 to 858.

CHAPTER I.

General considerations

This is not the first occasion on which the problem of repeating track-signals in the cabs of locomotives has been a subject for discussion. On the other hand it can be stated that for many years past it has attracted the attention of the most important of the Railway Administrations; but it must also be admitted that the administrations have not welcomed it with the enthusiasm and interest in its application that was deserving of the importance of the question; this was because nearly all their technical officials feared that repeating the track-signals in the cabs of the locomotives would tend to decrease the safety of railway working rather than to increase it, by distracting the attention of the driver from directly observing the track-signals.

It is not necessary here to repeat the criticisms on cab-signals that have been made by the leading technical officials of the Railways against the use of cab-signals, nor the thoroughly well-known arguments set out by Mr. Blum, inspector of constructional work on the Prussian State Railways, in relation to these objections.

Actually these objections which a more thorough examination of the problem showed to be erroneous, led to quite paradoxical conclusions, and in regard to this we recall the remarks made by the late Mr. Weissenbruch, manager of the Belgian State Railways, and published in the *Bulletin of the International Railway Association* (for April 1920, p. 173).

More accurate statistics relating to the cases of failure to observe the signals, quite apart from whether such failure had resulted in any accident or not, to-

(1) This question runs as follows : « Repeating and recording the track signals on the locomotive. Different systems already used or tried. Results obtained. — Recording the running speed of locomotives. »

gether with the improvements that had meanwhile been effected in the construction and reliability of the repeating apparatus, have led the Railway Administrations to undertake trials and even to instal systems of cab-signalling of their own accord. It must not, however, be forgotten that they were also urged to do so by the pressure of public opinion which had been roused by the serious character of many bad accidents due to failure in observing the track-signals.

In fact, it must be recognized that today, the increase in density of traffic, the increase in speed, and the increased complication in the signalling systems at great junctions, have made the work of the driver much harder in regard to looking out for and picking up the signals that he must obey. It must be added that the body of the locomotive in front of the cab has now grown to such a large size that it forms a great obstacle to the field of observation of the driver, particularly on curves : moreover the height of the chimney has now been reduced to such an extent that the smoke and exhaust steam are driven down, particularly at high speeds, in great clouds at the sides of the locomotive and that these also contribute to rendering the track-signals less easily visible.

It must therefore be recognized that the fitting of cab-signals on locomotives now appears to have become an absolute necessity; it is only a question of ascertaining to what extent and in what form they should be adopted, and whether their adoption will permit of any simplification being made in the arrangement of the track-signals.

With this object we addressed a list of questions to all the administrations which belong to the International Railway Association (except those of France). A Summary of the replies that we have received relating to each question or group of questions is given in appendixes A, B, C and D.

CHAPTER II.

Cab-signals : Classification and functions.

Amongst the railway administrations that received our list of questions, those that have made trials of cab-signals on locomotives are the following :

Belgium : Belgian State Railways.

United States (America) : Erie Railroad, Southern Railway System.

Great Britain and Ireland : Great Central Railway, Great Eastern Railway, Great Western Railway, London & South Western Railway, North Eastern Railway, North Staffordshire Railway.

Australia : New South Wales Government Railways.

Holland : Netherlands State Railways.

Sweden : Swedish State Railways.

Although these administrations accept the fundamental principles of the problem they do not agree in detail regarding the form and extent of its application. In fact they adopt different schemes for working which may be analysed as follows :

1° The system adopted confines itself exclusively to attracting the attention of the driver by giving him a warning of some kind when approaching the track signals;

2° The system adopted repeats in the locomotive cab the indication given by the position of the track-signals while giving warning on approaching them;

3° The system adopted is not limited to the repetition of indications given by the position of the track-signals or to giv-

ing a simple warning on approaching them, but it also produces automatic application of the brakes whenever the driver fails to obey the indication received either by the track signals or by the repeating apparatus (cab-signals);

4° The system adopted causes automatic application of the brakes according to the indications of the track signals, independently of any action of the driver.

These four systems represent the gradual transition from the conception of a simple warning for the driver of his approaching the track signals to that of the substitution of an automatic apparatus for the driver, relieving him of the responsibility for obeying the track-signals. Closely related to the question of stopping by the automatic application of the brakes there is also the question of recording the position of the track-signals in order to compel the driver, so far as possible, himself to keep a look-out on the track and thus to provide two factors, the man and the apparatus, and to rely on the joint probability dependent on their simultaneous actions rather than on the single probability of each individually.

With regard to the extended use of the system of cab-signalling some administrations confine themselves merely to repeating the distant signals; others repeat either the distant signals or the home signals. Finally, there are some administrations that foresee the possibility of abolishing the distant (track) signals by substituting for them the cab-signals given on the locomotive by the repeating apparatus.

The idea of automatic action is preferred by the Administration of the Belgian State Railways, which desires to repeat absolute stop signals and the distant signals on some lines of its system and at the same time to adopt automatic application of the brakes, according to the following scheme :

a) Sounding a whistle 200 m. (220 yards) before arriving at a distant signal when this is standing at danger; the whistle being stopped only by the action of the driver;

b) Sounding a different whistle when the distant signal stands at line-clear;

c) Should the driver fail to silence the whistle requiring him to stop, a gradual and automatic application of the brakes should take place in the case of a distant signal;

d) Automatic and immediate application of the brakes in the event of passing a home signal at danger.

The cab-signalling system adopted on the Great Eastern Railway meets these same conditions and an analogous programme has been adopted by the Southern Railway System of the United States of America; this administration, moreover, adopts automatic application of the brakes when the running speed of the train exceeds the permissible limit so as to reduce the speed to this limit. In this case the repeating apparatus is fitted with a recording strip on which is recorded the taking off of the brakes by the driver after they have been put on automatically.

The programme of the Great Western Railway differs from the preceding in that it is limited to repeating distant signals only without any form of recording gear.

The company working the Netherland Railways, while recognising the advantages and the opportunity for operating the brakes automatically and while comprising this in its programme, is of the opinion that it is unnecessary and even disadvantageous to adopt any form of cab-signalling; it is thought better to compel the driver himself to keep a look-

out on the track and to have a constant check on him by giving him the facility, when he has seen a track-signal, for preventing the automatic working of the brakes. Should he fail to do so, the automatic application of the brakes is recorded with the object of affording an indisputable check on the want of attention of the driver.

The other administrations prefer pure and simple repetition of the signals without any automatic application of the brakes.

Nevertheless the Reliostop repeating system adopted by the Great Central Railway, although simply limited to warning the driver on approaching distant signals, without indicating the position of the arm and without any form of recording gear, provides, notwithstanding this, for automatic application of the brakes should the driver run past a home signal standing at « danger ».

The London & South Western Railway has adopted repeating distant signals and stop signals as well as the recording of their positions; but in the reply of this Railway to our list of questions it is stated that the visual repeating apparatus should be so placed in the locomotive cab as not to prevent the driver from having a free view outside.

The North Eastern Railway similarly adopts the repeating of distant signals and stop signals, while drawing attention to the fact that this repeating should be performed as far as possible before arriving at the signal in order that the driver may himself have sufficient time to check the cab signal with the indication given by the position of the track-signal. Moreover, should the driver note the position of the track-signal in time he can put the apparatus out of gear and prevent any record from being made.

The North Staffordshire Railway and the New South Wales Government Railways limit themselves to repeating distant signals only; and require that, while not using any recording apparatus, the repeated signal shall remain in position for sufficient time to be certain of attracting the attention of the driver.

The Roumanian State Railways, although they have not yet adopted or tried any repeating system, hold an opinion different from that of all the administrations already mentioned; actually they express preference for repeating only the stop signals, between the distant signals and the stop signals, provided that it can be ensured that the indications given by the cab signal are perfectly reliable for regularity of working and clearness.

The Swedish State Railways have made no trials; it should, however, be noted that on some of their electric automotor vehicles working with continuous current, an arrangement has been installed for the automatic application of the brakes at a distance of about 50 metres in front of the home signal at a station in the case when such signal is standing at « danger ».

CHAPTER III.

Mechanical repeating apparatus.

In order to comply with the various working conditions required by the administrations in the programmes which have been summarized above, a large number of appliances and repeating systems have been designed and tested.

We shall now briefly review the more important repeating appliances which we shall divide into four classes : mechanical, electrical, electro-mechanical, and electro-magnetic appliances.

Amongst mechanical appliances the most characteristic apparatus is that of

Van Braam which was designed and constructed to meet the programme set forth in the Circular Letter of the French Minister of Public Works dated 18 september 1899. This programme may be summarized in the two following proposals :

1° To ensure the automatic application of the continuous brake, provided that a recording apparatus enables any lapse on the part of the driver to be recorded;

2° To ensure that the apparatus shall provide both a warning and a simultaneous record.

The apparatus is actually operated in the following manner : on approaching a distant signal, standing at danger, the driver receives warning by an alarm whistle and the appearance of a visual signal in the locomotive cab showing the position of the signal that has been passed. In the case of a home signal the alarm whistle continues to blow until the chief guard of the train takes action to restore the apparatus to its normal position, by means of a push button which he alone can work. Moreover by connecting the apparatus to the continuous-brake train-pipe automatic action may be obtained for this — partial in the case of a distant signal standing at danger — or complete in the case of a home signal at danger.

This apparatus has been described in the report of Mr. Maison on question XII to the Rome Congress [1].

The Van Braam apparatus has been tested on the French, Prussian, Belgian and Dutch Railways; the results obtained however, were not satisfactory, mainly on account of fairly frequent cases of incorrect working of the apparatus. In order to avoid these disadvantages the inventor modified his apparatus by eliminating the automatic working of the brakes and adopting four striking levers with springs, arranged in pairs on both sides of the locomotive, one pair being used for forward running and the other pair for reverse.

Notwithstanding the modifications made it would appear that the results of the trials made with the new type of apparatus do not appear to have been very satisfactory, because the Belgian State Railway and the Dutch State Railways state that they have been compelled to abandon it.

In fact these administrations state that in snowy weather it was necessary to lock the treadles and confine their indication to that of the approach to a track-signal; and it is quite certain that, in winter, bad weather must interfere with the working of the apparatus.

Notwithstanding the small success that attended the trial of the Van Braam repeating apparatus, the Belgian State Railway has subsequently made numerous trials of other mechanical appliances amongst which the most interesting is Sneyers' apparatus [2]. This apparatus depended, in its earlier type, on the use of a brush of springy steel wire placed on the track and acting on a mechanical arrangement (integrator) carried on the locomotive, which opened a valve and sounded the whistle by means of compressed air.

It is perhaps of interest to recall that the Raven apparatus [3] which, in its earliest form was entirely mechanical, is still fitted on 1 488 locomotives running over the most important line of the

[1] See *Bulletin of the International Railway Association*, November 1921, p. 1709.

[2] See *Bulletin of the International Railway Association*, April 1920, p. 184.

[3] See *Bulletin of the Railway Congress*, January 1912, p. 84.

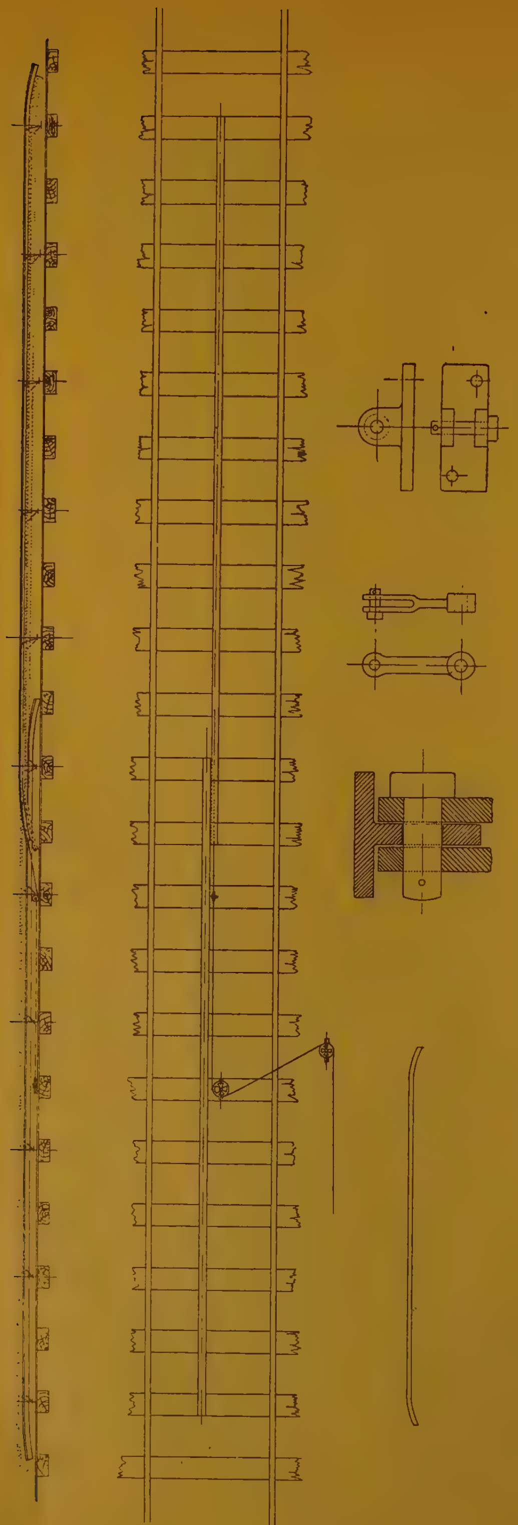


Fig. 1. — General arrangement of treadles. — Jefcoat cab-signalling system.

North Eastern Railway system between York and Alnmouth for a length of 116 miles. It is extremely simple, consisting of a contact treadle connected to the signal by rodding, in such manner that when the signal is at « danger » the treadle is raised and can come into contact with a striker carried on the locomotive. The shock transmitted from the treadle to the striker works a small whistle in the locomotive cab and at the same time applies the Westinghouse brake, the application of which continues until the driver takes action to restore the apparatus to its normal position. If the locomotive should not be fitted with the Westinghouse brake the whistle is blown by steam.

The apparatus invented by Mr. H. Jefcoat also belongs to the class of mechanical apparatus, of which it has most of the essential features; the repeating of the positions of the track-signals at « line clear » and « danger » is not caused by a single treadle capable of taking up two different positions, but, on the other hand, it is caused by two different treadles entirely separate from each other. These treadles are so placed in the track that they balance each other, being connected together in such manner that the depression of one assists in the raising of the other. This arrangement was adopted by the inventor with the object of reducing to a minimum the additional load that is thrown on the signal transmission gear when this has also to actuate the treadle.

Actually in this system there are two treadles connected to the distant signals and two treadles connected to the home signals; these treadles, acting independently of each other through three suspended strikers carried on the locomotive, produce the repeating of the signal as a cab signal which is simultaneously

visible and audible. There are two quite different indications given for distant signals and for home signals standing at « danger » and a third indication for both kinds of signal when standing at « line clear ».

The treadles are arranged between the rails, side by side, in the following manner : for a distant signal the treadle that gives the « danger » indication is always arranged exactly in the centre of the track and that which shows « line clear » is placed a little nearer to the left-hand rail; on the other hand for a stop signal the treadle that shows « line-clear » is in the centre of the track, but the treadle giving the stop indication is on the other side of the centre of the track, that is to say nearer to the right-hand rail.

Three striking levers are arranged on the locomotive in a similar manner side by side the middle one being always operated by a treadle corresponding to a distant signal at « danger », the right-hand one by any treadle standing at the position corresponding to « line-clear » and the left-hand by a treadle corresponding in position to a home signal standing at « danger ». It may, however, be remarked that the number of strikers could be increased so as to produce other repetitions if such were desired.

Figure 1 shows the details relating to the arrangement of the treadles corresponding to a distant signal : they are placed in advance of this, at a distance depending on the gradient of the section preceding the signal, in such manner as to allow proper time for warning the driver. On some stretches of track, on which the system has been tried, with a gradient of 1 in. 150, the treadles were placed at a distance of about 440 yards before the distant signal, giving a warning of fifteen seconds for a speed of 60 miles per hour.

The treadles are secured to the track in the following manner : flat steel plates 25 ft. 10 in. by 3 5/8 inches wide and 1/4 inch thick are carried on the sleepers. In each bar, at intervals of 5 feet, two holes 11/16 inch in diameter are drilled 7 inches apart.

These holes serve for attaching the fixed bearings shown in figure 1. These carry two arms ending in a fork into which the web of the T-section treadle enters; the treadle is 30 feet long, 2 1/2 inches wide by 2 1/2 inches deep and 3/8 inch thick.

These forked arms are of different lengths according to their position from the end of the treadle. The danger indication, that is to say that for stopping, is given by the treadle B, which is fitted with five arms which are entirely independent, except the operating arm which is common to it (B) and to the treadle A; this arm is operated by the signal wire. The arms carrying the treadle B taken in the order in which they are arranged according to the direction of running of the locomotive which meets the treadle are of the following lengths : No. 5 : 5 15/16 inches; No. 4 : 6 1/4 inches; No. 3 : 6 1/2 inches; No. 2 : 6 13/16 inches; No. 1 : 7 1/8 inches. Similarly the arms which carry the treadle A have the following lengths : No. 5 : 6 7/16 inches; No. 4 : 6 3/4 inches; No. 3 : 7 1/16 inches.

Figure 2 shows the working of the operating lever. Two arms are keyed to a horizontal rocking shaft, the left-hand arm carrying the treadle B which gives the « danger » indication and the right-hand arm carrying the treadle A which gives the « line-clear » indication.

Under normal conditions when the distant signal stands at « line-clear » the front end of the treadle B is 1/2 inch below the line of contact of the striking

levers on the locomotive; but as the locomotive runs over the treadle the level of this rises gradually till at the further end it is 1 inch above the line of contact of the striking levers. At the same time the treadle A is in its lower position in which its forward end is 3 1/4 inches and its further end 1 3/4 inches below the line of contact. Both of the treadles terminate in inclined planes : the forward end has a slope of 3 1/2 inches in 2 ft. 3 in. and the further end a slope of 5 inches in 2 ft. 9 in. so that when each treadle is in its lower position in all cases it comes up to the level of the rails.

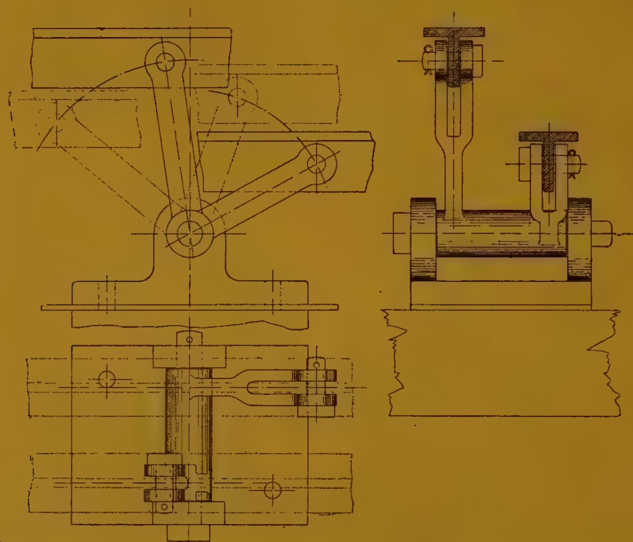


Fig. 2. — Details of operating lever and brackets in the Jefcoat cab-signalling system.

The further end of treadle B is connected by wire to the track-signal in such manner that when this is set to « line-clear » the treadle B moves to the left and consequently is brought to its lower position, in which its ends are respectively 3 inches and 1 1/2 inches below the contact level of the striking levers; the result is it cannot in any way affect the apparatus on the locomotive. At the same time the lever raises the treadle A which rises to the level formerly occupied by the treadle B.

In an exactly similar manner the stop signal is also connected to two treadles of which that which gives the indication of « line clear » occupies the same position relatively to the rails, as that occupied in the case of the distant signal and that which gives the indication for stop is on the right hand of the centre of the track so as to operate the right-hand lever instead of the centre lever.

The striking levers are contained in a metal box (fig. 3) which can be secured to the frame of the locomotive at a height which can be adjusted according to requirements. The striking levers are fitted with opposed spiral springs, the resistance of which must be overcome to obtain the raising of the striking lever on passing over the treadles; when a

treadle has been run over the springs restore the lever in question to its original position.

At the upper end (fig. 3) of the central suspended lever *a* for distant signal at « danger » a pulley *b* is carried, over which a metal wire *c* runs of which the end c^2 is permanently secured to the box, and the other end is connected to a spring *d;* the transmission is completed by two intermediate pulleys c^3 c^3.

To the other end of the spring *d* is secured a second metal wire *e*, which is attached to the lever f^2 of the whistle *f*, and to a second spring *g;* this spring in turn works a third wire *h* which is connected to the lever *j* of the brake. Moreover, above the spring *d* and on the wire *e* is arranged a catch e^2 which, when the wire *e* is pulled, comes into contact with another fixed catch e^3, and, near the spring *g*, a movable catch e^4 is arranged on the wire *e* which comes into contact with the fixed stops e^5 or e^6.

It is therefore evident that any raising of the lever *a* produces displacement of the pulley *b* and that the wire *c* stretches the spring *d*. If the displacement of the pulley *b* were excessive owing to an irregularity in the contact made by the striking lever with the treadle, the catch e^2 on meeting catch e^3 would limit the movement of the wire *e* and the extra pull would come entirely on the spring *d*. The displacement of the wire *e*, however, suffices in all cases to cause the opening of the whistle *f*, the working of which may be interrupted by operating the lever f^2, and at the same time making gradual application of the brake by displacing the lever *j* in the direction of A.

The brake may be taken off by bringing the lever *j* back to its normal position : the catches e^4 and e^5 relate to the regularity of the operation performed by the driver. At the same time that the whistle sounds the alarm and that the brake is applied, a red visible signal is caused to appear electrically in the cab of the locomotive and a loud bell starts ringing which cannot be stopped until the driver has brought the train to rest.

If the treadle B were lowered and the treadle A were raised the lever to the right of *a* would be raised — distant signal at « line-clear » — which lever on being raised closes an electric circuit and causes a green visible signal to appear in the cab of the locomotive and a small bell to ring.

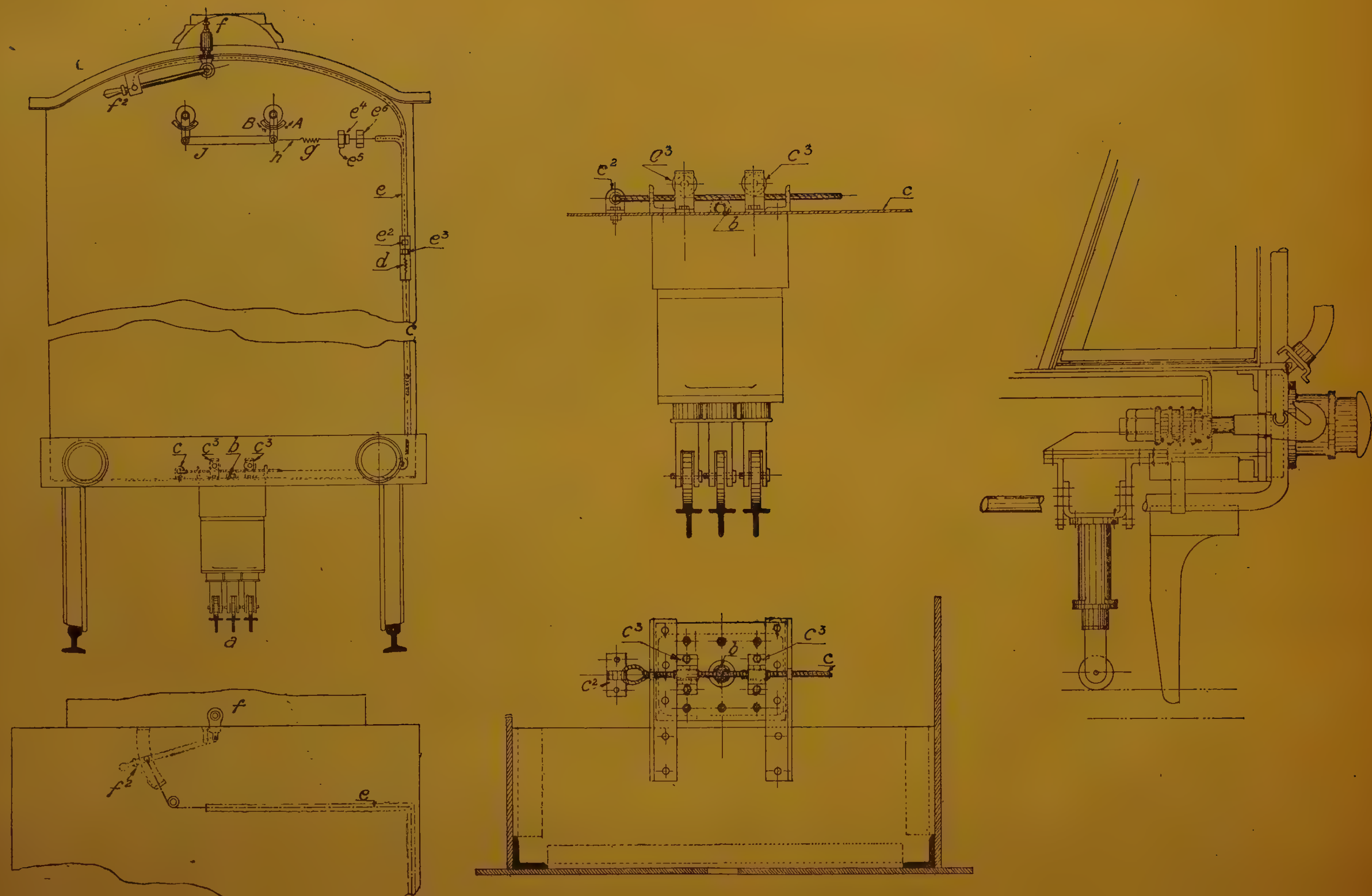
When the train approaches an absolute stop (home) signal, and when the preceding distant signal is standing at danger the driver is warned to apply the brakes. If the stop signal is at « line-clear » the lever to the right of *a* will be operated; if, on the other hand, it is at « danger » the lever of the left will be actuated and the rising of this will produce a second application of the brake, the blowing of an alarm whistle, and the appearance of a red visible signal in the cab of the locomotive.

If the locomotive should happen to be running tender first the two side striking levers would be transposed; in this case a special switch is provided for altering their functions.

It is important to note that the working of the apparatus is essentially positive, because the treadle A giving the indication of « line-clear » is normally in its lower position.

There is no need to enlarge on the subject of other types of apparatus of this kind; it may merely be mentioned that almost all the railway administrations that have made trials relating to the question of repeating signals have commenced by experiments with mechanically operated apparatus.

As the result of these trials it has been


f
f²
B
A
J
h
g
e⁴
e⁶
e⁵
e
e²
e³
d
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C
C³
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a
c²
C³
c
b
C³
C³
b
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f
f²
e

possible to appreciate that, in the construction of such apparatus, some serious difficulties must be avoided, such as the destructive effects due to the considerable inertia to be overcome by the shock, particularly at very high speeds; the increased difficulty of operating the signals by reason of the necessity for connecting to the signal transmission the movable treadles placed in the track; and any incorrect working which may be caused by unforeseen obstacles encountered on the track.

CHAPTER IV.

Electric repeating apparatus

These appliances are in much more general use than mechanical apparatus thanks to the simplicity of the principle on which they are nearly all based : *the train when passing over special gear connected with the signal of which the indications are to be repeated, closes or opens a circuit by means of a contact which, either directly or indirectly, causes the working of the repeating apparatus and in some cases of the continuous brake also.* A simple contact for opening or closing a circuit can be constructed without fear of destructive shocks and with great certainty of action, even at very high speeds; it is therefore evident, from this point of view, that the electric repeating appliances show great superiority over the mechanical apparatus.

The electrical repeating appliances that have been invented are very numerous; amongst these we may mention that invented by the Belgian, M. Vital César (1), a very complete description of which is made by Mr. L. Weissenbruch in his very interesting article on signals for giving warning in fog.

This apparatus is free from the most serious defects found in other appliances using the Lartigue type of crocodile, that is to say, that of not always acting in the direction of ensuring safety; a direct contact between the rail and the treadles, moreover, cannot give rise to an indication of « line-clear » even when the signal is at « danger ». It has, however, been sufficiently demonstrated in practice that the working of the apparatus is not satisfactory. During the period of the trials derangements and failures were very numerous and the greater number of these were caused either by the breakage of a line wire or of the treadle connexion or by defective insulation of parts (treadles, brushes, etc.) or by failures of the switch. The latter are particularly to be feared because it is evident that if a switch closes the track circuit incorrectly it would still be possible to give the driver an indication of « line-clear » while the signal was actually standing at « danger ». Another very important cause of derangement is due to the fact that the batteries are carried on the locomotive : although this allows of their being inspected more easily, at the same time it makes them more liable to become run down as the result of polarization. Apart from their being continuously at work, the electro-magnet circuit being permanently closed is itself a very important cause of the batteries becoming exhausted. If, therefore, the system were to come into general use, it would be necessary to maintain the batteries in the running sheds, this would place on the shed staff work they were not accustomed to, and would doubtless be much more costly than the maintenance of batteries on the ground. It is, moreover, easy to design an arrangement that

(1) See *Bulletin of the International Railway Association*, April 1920, p. 186.

enables the state of the batteries to be checked by causing the current to pass through the cabin from which the signal is operated; this is the method most frequently adopted to-day in practice for avoiding the accidental running down of batteries on the ground.

Another fairly frequent cause of failure in the working of the Cesar apparatus is the small quantity of the extra current which is at the same time the original feature and the point of weakness of the system. Finally, even making allowance for the numerous cases of irregular working of the whistle, which may be due to many causes, and to the necessity for a positive working of the apparatus — an arrangement which must always be very delicate and accurate — there remains the problem to be solved of ensuring contact in winter between the brushes and the treadle in case of snow, ice or other bad weather effects. To overcome this latter trouble, amongst other methods the following systems have been proposed :

1° The adoption of protective brushes arranged in the front of the locomotive, or of other similar arrangements, intended to remove the covering of snow, ice, or other non-conducting substance which prevents contact from being made; in the case of hoar frost these difficulties may be avoided by making use of paraffin for preventing the adhesion of hoar-frost to the objects which it covers; in this case it is necessary to arrange for employees to paint the treadles with paraffin during severe weather;

2° To adopt a much greater length for the treadles, up to 18 or 20 m. (59 feet or 65 ft. 7 in.) substituting, moreover, for the smooth brass sheet, with which they are usually covered, a surface formed as a long grating of mild-steel strips which can be maintained at a fixed distance by means of stays carried on the sleepers by the intervention of metal supports from which they can be insulated by wooden shoes;

3° The use of an inverted channel-iron with sharp edges or a grid of special form.

Naturally, the further one departs from the type of treadle having a smooth surface, the more does the apparatus lose its characteristic advantage of ensuring simple and easy contact without shocks or vibration or other causes of damage to the parts; at the same time the apparatus loses more and more its capability of working satisfactorily at the high speeds.

It is therefore necessary, if one does not wish to adopt treadles with smooth surfaces, to strengthen the brushes; in fact they are to-day formed of strong steel strip carried in a double housing of metal and insulated from the body of this by a thick sheet of micanite capable of resisting the destructive action of the heat encountered from heaps of cinders that have not been properly quenched or from very hot clinker over which the locomotive may have been stopped by chance.

To resume, it must be recognized that this apparatus is extremely ingenious; however, as the result of the trials which have been made on the lines of the Belgian State Railway System, its adoption has not been recommended.

CHAPTER V.

Electro-mechanical repeating apparatus.

Another very important class of repeating apparatus is that of the electro-mechanical appliances. These appliances, which to-day comprise the most highly

developed systems, are based upon the following principle : *the contact between the locomotive and the treadle does not serve exclusively for closing an electric circuit, but also produces the displacement of some movable parts, the movement of which is capable of working the apparatus.*

The most simple apparatus coming into this class is without doubt the well-known type of the *Great Western Railway Company*. It works in the following manner :

A treadle R (fig. 4) consisting of an inverted T iron is placed in the centre of the track; this form has been adopted because it has the advantage of offering only a very small surface for the accumulation of snow and ice, and thus makes the working of the apparatus possible even in winter and under bad weather conditions.

The treadle R is carried on a wooden support and is suitably insulated by adopting the arrangement shown in figure 4; it has a length of 60 feet (18.30 m.) on express lines, and of 40 feet (12.20 m.) on slow tracks and branch lines : its highest point is 4 inches (102 mm.) above the rail level (fig. 4), and it is arranged with inclined portions at its ends with a view to reducing the shocks produced by meeting the contact shoe carried on the locomotive. The treadle is electrically connected by a telegraph wire to a switch S' placed in the signal cabin, which enables it to be connected to or disconnected from a battery B', of which the positive pole is earthed, according to whether the signal-lever is in its position for « line-clear » or for « danger », the switch S' is closed or open.

When a signal is passed by a locomotive a contact shoe L, which is attached to the locomotive, rubs on the treadle; normally the shoe, which would hang downwards owing to its weight, is balanced by a spring tending to hold it up, and is so adjusted that at its lowest it is 2 1/2 inches (64 mm.) above the level of the rail; that is to say, that when it runs over a treadle it will be necessary for it to rise 1 1/2 inches (38 mm.). On the locomotive there is an arrangement of two electro-magnets E and E', the armatures of which are connected by a bridge in such manner that a fairly powerful common armature K is formed, when it is held up by the exciting of the one or the other of the electro-magnets, for ensuring the closing of the valve V of the whistle W. Under normal conditions the armature K is in contact, because the electro-magnet E is always connected through a local circuit on the locomotive, comprising the battery B and the switch S mechanically connected to the shoe L. But when the shoe L, in passing over the treadle, is raised by at least 1/2 inch (13 mm.) above its normal position the switch S is opened; the local circuit of E is then interrupted, the electro-magnet ceases to be excited and the armature K opens the valve V of the whistle. This happens when the corresponding signal is at « danger », that is to say when the switch S' is open and the track circuit is interrupted; when the shoe leaves the treadle the shoe L is returned by its weight to normal position in which it is maintained by the action of the retaining spring mentioned, the switch S is closed and the electro-magnet E being excited can again attract the armature K which closes the valve V and stops the sounding of the whistle W. If, on the other hand, the signal is at line-clear, the switch S' is closed and the current sent by the battery B' may, in passing through the contact R-L and the connexions shown in figure 4, excite the electro-magnet E' of which the wind-

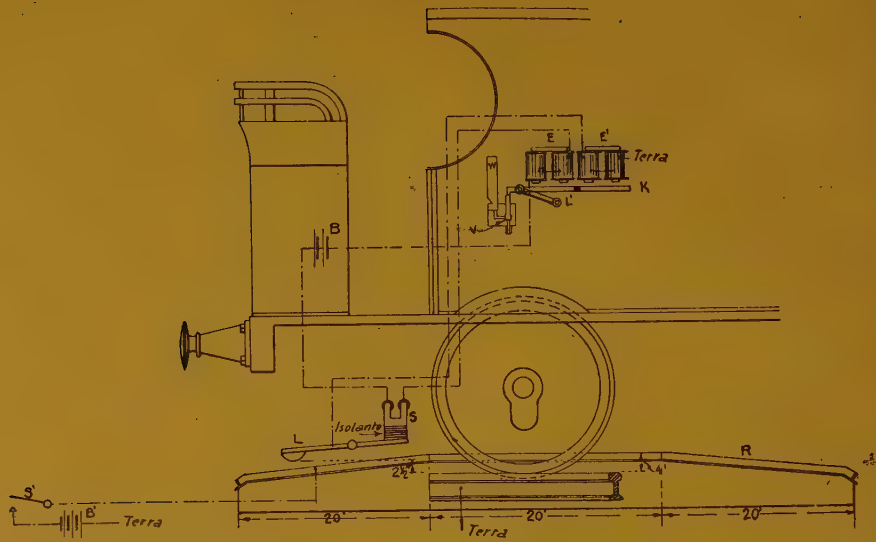

Fig. 4. — Great Western Railway type of cab-signalling apparatus.

Explanation of Italian terms : Terra = Earth. — Isolante = Insulator

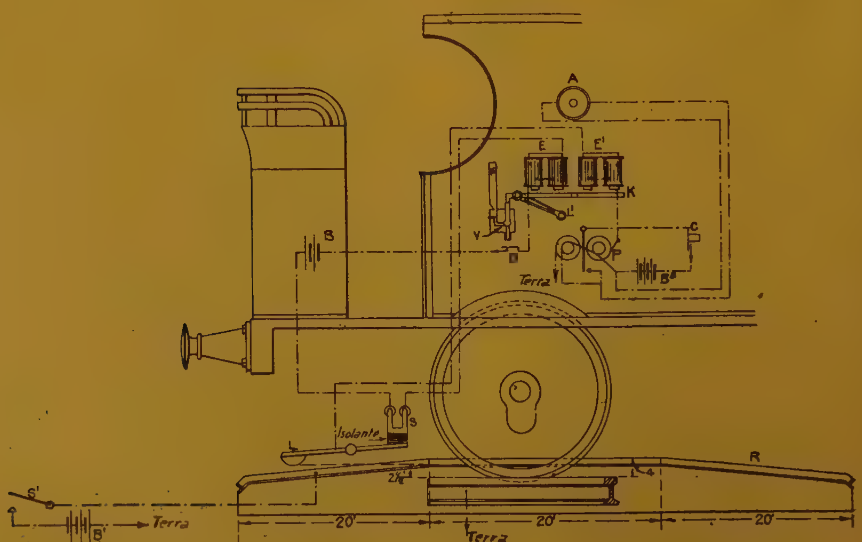

Fig. 5. — Great Western Railway type of cab-signalling apparatus.

ing is electrically connected on the one hand to the shoe L and on the other hand to earth through the body of the locomotive and the track-rails. Under these conditions the shoe when passing over the treadle not only opens the switch S, but also closes the circuit of E' : consequently the armature K is no longer held by the electro-magnet E, but by the electro-magnet E' and the whistle cannot sound. However, as it is desired in all cases to give an indication to the driver, even when the signal is at « line-clear », the current leaving the battery B' running through E' (fig. 5) does not go direct to earth but passes through a polarized relay P which attracts its armature and closes a second local circuit comprising a battery B[a] and a bell A. The polarized relay P has a second winding which serves to maintain the bell circuit closed, in such manner that this can continue to ring even after the shoe has left the treadle and until the driver takes action himself, and, by pressing on the push C, momentarily interrupts the bell circuit. There is, moreover, interposed in the circuit of the electro-magnet E, a spring contact D, actuated by a valve operated by steam, which causes the opening of the circuit and consequently gives the driver warning of danger when the pressure in the boiler falls below 205 lb. per square inch (14 atmospheres).

Figure 6 shows the arrangement of the apparatus on the locomotive.

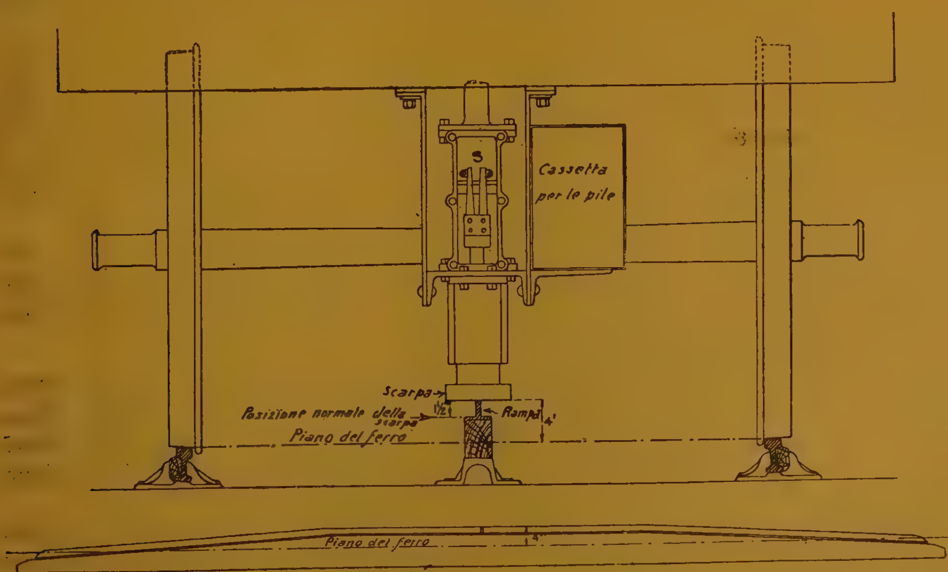

Fig. 6. — Great Western Railway type of cab-signalling apparatus.

Explanation of Italian terms : Piano del ferro = Rail level. — Scarpa = Shoe. — Posizione normale del'a scarpa = Normal position of the shoe. — Rampa = Incline (or ramp). — Cassetta per le pile = Battery box.

The simplicity of principle and of construction of this apparatus ensures good working, which is confirmed by the administration of the Great Western Railway as the result of fairly long trials made on a large scale. It cannot be

doubted that the difficulties due to the presence of three electric circuits and to the contact between the movable shoe of the locomotive and treadle could never be entirely eliminated; a brush contact might probably improve the working of the apparatus.

The administration of the Great Western Railway has abandoned on some single line sections the distant signals and has substituted repeating apparatus for these.

In the early form of the apparatus, it worked exclusively as a repeater of the track-signals; it was afterwards desired to add the application of the brake to that of the steam whistle in order to obtain a gradual and automatic slowing of the train when the signal is at « danger ». In the case of single tracks the arrangement placed in the signalman's cabin enables him to send negative current through the track-circuit instead of positive current, if the treadle is to meet the shoe of a train running in the opposite direction to that covered by the signal. The reversal of the current may be obtained in a very simple manner by inverting the electric connexions of the group of batteries B' with the treadle R; these connexions normally ensure a negative current and the operation of setting the signal to « line clear » alone enables positive current to be substituted for it and to cause the working of the apparatus. With the object of avoiding the possibility of the signalman making a mistake, during the throwing over of the levers, by sending a positive current instead of a negative current the levers controlling the signal and those controlling the electric switches must be connected to each other and suitably interlocked in order to make the operations automatic.

The Raven apparatus used by the administration of the North Eastern Railway, on the Darlington-Richmond branch on which it is still at work, somewhat resembles the Great Western Railway apparatus although some modifications have been made in the apparatus that have been found necessary from the experience gained in the last few years. From the original paper read by Sir Vincent Raven [1] in London on 18 December 1914 before the Institution of Mechanical Engineers, and the particulars which have been supplied to us by the administration in question, relating to the modifications that have since been made, it will be seen that in this apparatus it is proposed :

1° To advise the driver of his approach to a point where signals are to be looked for;

2° To give the driver the necessary information with regard to the position of his signals and to prevent him from mistaking other signals for his own; in fact this trouble has been often experienced in the case of junctions;

3° To control the driver by the cab-signals until he has passed the last signal controlling entrance into the section beyond.

It is necessary to recall that the Raven system takes account of all three classes of signals in use on the English railways, that is to say distant signals, home signals and advance signals.

The adoption of a number of small semaphores S, equal to that of the tracks of the junctions, represents a modification that has recently been introduced into the Raven apparatus : this, in its earlier form, had only a single small semaphore and a pointer operated by a

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(1) See *Bulletin of the Railway Congress*, number for January 1912, p. 84.

second armature of the electro-magnets : this pointer served to act as an indicator of the direction to be taken.

Another modification that has been recently made in this apparatus is the automatic working of the brakes as shown in figure 7.

The brake valve placed on the train pipe is balanced by a spring controlled through the link-work N-Q, by the armature K''' of the electro-magnets E_4-E_4 permanently excited by the local batteries P'. The exciting circuit of the electro-magnets E_4-E_4 is P'-R'-E_4-E_4-12-*f*-13-14-15-P', if it is the question of the small semaphore S, or by P'-R'E_4-E_4-12-*f'*-13-14-15-D', if it is the question of the small semaphore S', or finally if it includes the contact for the automatic control : P'-R'-E_4-E_4-12-f''-13-14-15-0'. Under normal conditions the small semaphores S and S' are in the position of line-clear and the shoe S*h* is held in its lowered position; then the contacts *f*-*f'* and *f''*, as well as the brake valve, are closed.

When, on the other hand, the small semaphores S and S' are at danger the contacts *f* and *f'* are open; in this case an interruption of *f''* produces immediate automatic application of the brake, because all the circuits which can produce excitation of the electro-magnets E_4-E_4 remain open. In order to produce an interruption of *f''* it is necessary that the shoe S*h*, having been displaced by meeting a treadle should immediately fall back into its lower position; with this object the tappets which cause interruption in the circuits have been arranged as shown in figure 7.

An application of the brake can therefore only be produced when any treadle has been passed over, whereas it does not take place if the train is stopped over a treadle. The application of the brakes is not instantaneous, but is produced gradually as the successive treadles are passed over, if it should happen after the warning given by the treadle A, that an absolute stop indication is given on the others and that this indication is maintained up to the last one. In any event, the driver can always cancel the application of the brake by pressing on the contact C, which resets the apparatus, when it is closed, to its initial position and consequently also closes the contacts *f* and *f'*. Finally the main switches R and R' allow the driver to put the whole apparatus out of action, that is to say to prevent it from working.

The diagram of the connexions of the track-circuits, which enable current to be sent from the cabin controlling the signals fitted with treadles, is very simple particularly if it is a question of a simple junction. In fact, in operating the levers of the cabin which set the signals to line-clear, the closing of the contacts shown in figure 7 is ensured at the same time; these connect the batteries placed in the signal cabin with the line wires. These wires are three in number : the first supplies the treadles B-C-D and forms a portion of the distant-signal circuit and of the home-signal circuit; the second and the third are connected respectively to the treadles E and E' and form part of the advance-signal circuit of track I, or of track II, of the junction.

Each of these wires is connected to an indicator in the cabin which enables the signalman to check whether the current has really passed through the treadles in question. It is necessary, however, to note that in this case the pointer of the indicator makes a partial rotation as it is controlled by the armature of a small relay, the excitation of which is not complete; in fact when the track circuit is open, that is to say when the train does

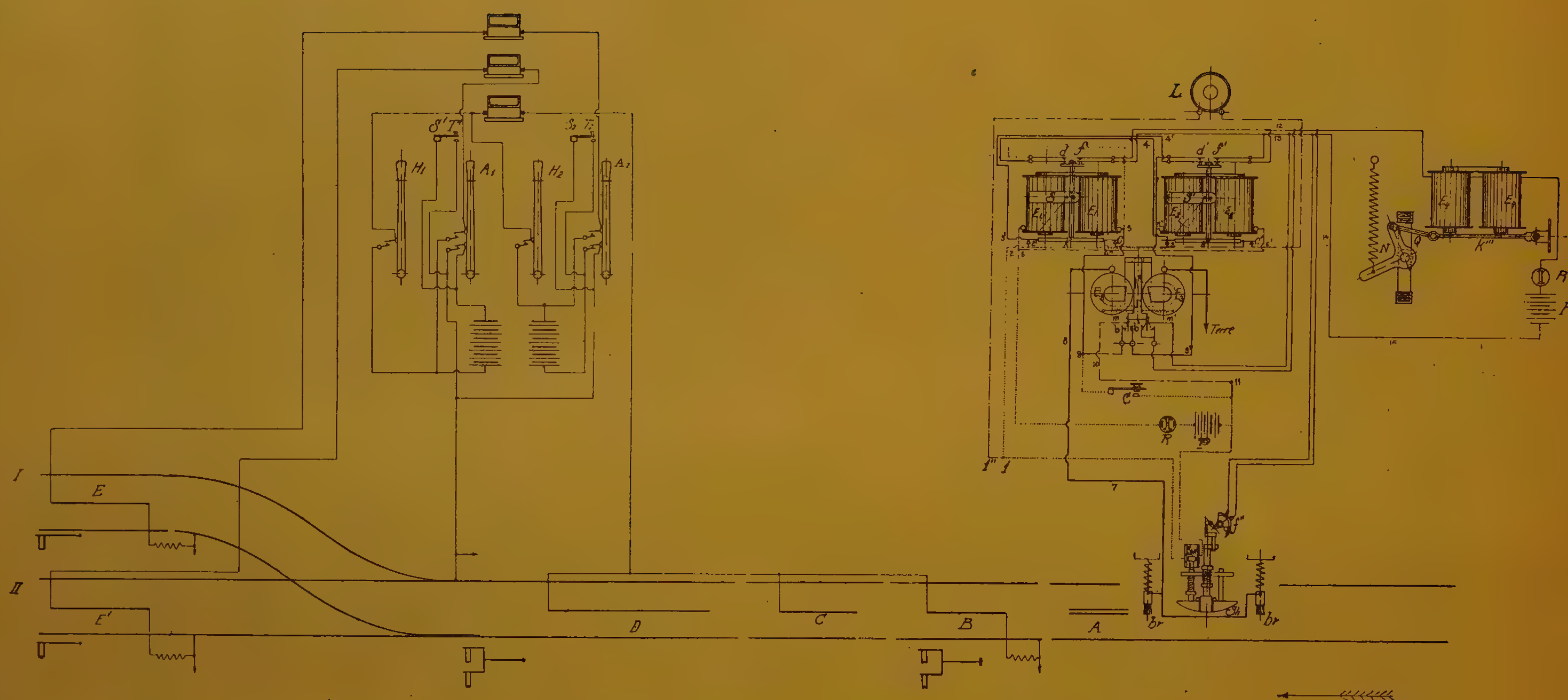

Fig. 7. — The Raven cab-signalling apparatus.

Explanation of French term : Terre = Earth.

not run over a treadle, the shunt current for exciting the relay is limited owing to the resistances which form part of the circuit. These resistances do not in any way prevent the working of the arrangement placed in the locomotive cab, during the time of passing over an electrified treadle. On the other hand, when the brushes b_r take current from the treadles a new circuit is made, in parallel with that for exciting the relays; the total resistance being in this event reduced, the exciting current is increased and the pointer performs its movement of rotation enabling the signalman to check whether there is any failure in the track circuits and whether the apparatus carried on the locomotive has worked properly. The levers H_1 and A_1 (fig. 7) relate to track I and the levers H_2 and A_2 to track II; the circuit completed by the operation of the H-levers — relating to the distant signals and the home signals — is not made complete until the operation of pulling over the A-levers relating to the advance signals has been effected. On the other hand, the operation of the latter is sufficient to ensure the closing of the corresponding circuits; it follows that when the signals are not all at line clear it is not possible to give the indication that the road is clear by means of the distant signals; whereas it is always possible to change the indication of the successive signals, whatever may be the indication previously given.

Moreover, the signalman has the keys S_1-T_1 and S_2-T_2 which enable him to interrupt the current sent to the treadles: by repeating this operation of interruption several times he displaces the arm of the small semaphore in the locomotive cab relating to the track in question, alternately from the position for « line clear » to that of absolute stop in such manner as to attract the attention of the driver. It is a question of the indication to be given to the driver to order him, if he has stopped his locomotive on the treadle D, to proceed as far as the treadles E or E', but without over-running them. Finally it is evident, as shown by the scheme of electric connexions given in figure 7, that the direction of the current sent to the treadles is respectively positive if the levers H_1-A_1 are operated and negative if the levers H_2-A_2 are worked.

The case has been shown here of a double track junction; but it is quite evident that the same arrangement might be adapted to any number of tracks whatever, by merely increasing the number of small semaphores S, and of groups of electro-magnets corresponding to these, as well as of the electro-magnets E_3-E_3, and the levers for operating the signals in the cabin with the corresponding track circuits.

There is no need here to make any criticism of this apparatus which is certainly very ingenious and satisfactory in working. However, it should be noted that the administration of the North Eastern Railway recognizes that the great number of failures that have arisen during the period of the trials has been caused by the breakage of the contact-pieces, whereas others have been caused by the rupture of the connexions, or by the formation of ice on the treadles.

In all the repeating appliances that we have described hitherto the mechanical portion is limited exclusively to causing the action of the electric portion which forms the most important part of the apparatus. There is another class of electro-mechanical apparatus in which the most important part is the mechanical gear; it should be remembered that there should be included amongst appli-

ances of this class the Syx [1] apparatus, which has been tried on the Great Eastern Railway System.

It must be admitted that the Syx apparatus is very ingenious and complete with regard to solving the problem of constructing a repeating apparatus, mechanically rather than electrically operated, and has met with considerable success in the effort to overcome very many difficulties by satisfying the main conditions to be met in the greater part of the working requirements. There is no need here to make a critical examination of this apparatus : practice will show to what extent it has been able to eliminate the disadvantages which have already been found and which are present in almost all mechanical and electrical apparatus.

We will terminate this series of descriptions of the electro-mechanical repeating appliances in actual use to-day, or only in course of trial by the various railway administrations, by giving a short description of the Buell repeating system tested on the Southern Railway System of the United States of America and the Reliostop system adopted by the Great Central Railway of Great Britain.

The conditions met by the Buell system require that the train should be stopped automatically, but the driver is free to take the brakes off, after they have been applied, by pressing a push-button in the cab : in this manner the locomotive is always kept under the control of the driver. In this system there are no striking levers or contact treadles; it is closely connected to the automatic signalling system installed on the track, but it can also be adapted to hand-operated signals. Derangements of essential parts of the apparatus, or failures of any kind, or even want of current, are immediately shown on the locomotive by the automatic application of the air brakes. The system will work at any, and even at very great speeds, and it is independent of bad weather. The apparatus used during the trials was so adjusted that application of the pneumatic brakes occurred about 2 500 ft. (750 m.) before any obstacle, or block section under abnormal conditions; nevertheless, even at very high speeds, the train will continue running without interruption if the driver acts immediately by pressing on the push-button in the cab; a special arrangement records his action in this event.

The apparatus arranged in the locomotive cab does not prevent the driver from carrying out the ordinary braking operations that may be necessary during the running of the train; the working of the brakes and their efficiency are not diminished; the apparatus can work, moreover, for either directions in which the train may be run.

The object which the inventor of the Buell system had in view was to obtain as perfect an appliance as possible acting in agreement with the fixed track signal system, in such manner that each system should supplement the other. It would have been of interest to publish complete diagrams showing the working of this apparatus with drawings and photographs of the appliances; the administration of the Southern Railway System, however, was not able to comply with our request, because the final form of the Buell system had not yet been made public as the trials had not yet been completed.

In order to effect the actual repetition in the cab of the indications of the track signals many arrangements were tried; but, in general, the system adopted in almost all the trials consisted of coloured lights

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[1] See *Bulletin of the International Railway Association*, November 1921, p. 1939.

accompanied by a small pneumatic whistle. Recording was obtained by means of a diagram or of a simple paper strip, moved at uniform speed and perforated by a pin actuated by air supplied from the brake-pipe; the apparatus is so arranged that it is not possible to apply the brake after the signal is repeated in the cab without recording the fact. It can be arranged that the paper strip on which the record is made can be marked either so that the driver can see the record made or that this is done out of sight. The general working of the apparatus is ensured by means of electricity and compressed air, and it has proved fairly satisfactory; the administration of the Southern Railway System has informed us that the disadvantages that have been found during the trials have been exclusively produced by failures in the electric connexions or in the joints, caused by the action of hot cinders or by a momentary interruption of the current : in any case, the result of the trials has been on the whole satisfactory.

The Reliostop system, tried on the lines of the Great Central Railway system in England, is based, as we have already said, on the following principle : it is required that complete repetition of the fixed track signals in the locomotive cab, should be avoided and it is only requisite that the driver shall be given warning in time of his approach to signals in order that he may himself be able to observe them.

The arrangement carried on the locomotive consists of a suspended striking lever which works a small valve; the air passes through this valve by the action of a second valve fitted with a diaphragm on the main train-pipe and at the same time a siren is caused to sound and give a sufficiently clear warning to the driver. When the striking lever has been displaced by the contact treadle in the track it does not return to its normal position until the driver takes action by means of a cylinder with a diaphragm which, by means of a valve, communicates with the main train-pipe or with the vacuum reservoir. The arrangement is, moreover, fitted with a small easily-broken wooden strip, compressed between two spring supports; when this piece of wood is broken as the result of meeting the fixed apparatus in the track a small valve is opened sending air to a second valve with a diaphragm of sufficient size to destroy the vacuum in the train-pipe and thus to produce full application of the brakes. This only happens when an absolute stop (home) signal has been run past at danger by the train to which it refers. In this case, in order to take the brakes off, it is necessary to replace the strip of wood that has been broken and this entails the stoppage of the train.

It should also be noted that the appliances on each locomotive comprise two striking levers and two easily broken strips of wood, there being a striking lever and a strip of wood on each side. It is not necessary to adjust the position of the levers and of the breakable parts; it is however possible to check their position from time to time by using suitable gauges. With the object of causing partial application of the brakes a short treadle is arranged on the track, about two feet long, horizontally in the six foot way. In order to make a full application of the brake a special apparatus is arranged in connexion with the stop signal, consisting of a vertical shaft the upper end of which carries a horizontal arm, which, being given a rotative movement when the signal is changed from « line-clear » to « stop », turns through 90°. Consequently when the signal stands at « line-clear » this arm is parallel with

the track; when, on the other hand, the signal stands at « danger », it is at right angles to the rails so that it breaks the wooden strip, carried on the locomotive, when it comes into contact with it. The working of the apparatus depends also entirely on that of the fixed apparatus, arranged on the track, the working of which is checked by an electric circuit running through the signal cabin; nevertheless, it is evident that any failure either of the track apparatus, or of that carried on the locomotive, would prevent the application of the brakes.

The administration of the Great Central Railway, however, states that the working of the Reliostop has been quite satisfactory and makes the observation that it works even at the highest speeds and is independent of all weather conditions.

CHAPTER VI.

Electro-magnetic repeating apparatus.

It follows from the brief description that we have made of the chief repeating appliances adopted, or merely tested by the administrations which have replied to our list of questions, that one of the most delicate elements in the problem is without doubt the contact between the part that moves with the locomotive and the fixed part arranged on the track. It is perhaps from this consideration that some inventors have made trials for solving the problem with an arrangement that, while making no actual contact between the fixed part and the moving part, yet produces, in a simple, sure and positive manner, the repetition of the fixed track-signals in the locomotive cab; and it is essentially with the object of eliminating any form of contact that these inventors have endeavoured to substitute electric, or electro-mechanical or electro-magnetic action for mechanical action. Those repeating appliances which, by the use of electro-magnetic waves, possess the merit of having reduced to the minimum the risks due to mass, velocity and inertia belong to this class of electro-magnetic appliances.

One of the first trials of apparatus of this class was made with the Perry-Prentice system, the trial of which gave good results on the London & South Western Railway; this apparatus was not however adopted on account of its high cost. As is well-known, the scientific basis of this system and of all other systems of this class, is the discovery made by Hertz that the presence of an oscillating current in a circuit having capacity and self-induction gives rise to disturbances in the surrounding ether which are known as electro-magnetic waves. Under the action of these waves a tube filled with metal filings, ordinarily known as a coherer, becomes a good conductor of electricity when it comes into the zone of the waves or is subjected to appreciable change in its electrical resistance.

The Perry-Prentice system consists of two groups of apparatus, one of which is placed on the track and the other on the train. The principal details of the first group are: the track circuit and the wave-producer or oscillator. The method of controlling the waves by the relay in the track circuit can be easily understood by examining the diagrams relating to three successive block sections. The generating appliance, that is the wave-producer or oscillator, comprises (fig. 8) the transformers T, the condensers C, and the discharge knobs P-P. An appliance of this kind is arranged at the end of each block section; from this point leave two wave-carrying wires W, one in each direction.

These wave-carrying wires W are ac-

tually identical with antennæ folded down into the horizontal plane and running over the whole length of the two contiguous sections. Along each section there are two wires H-G, the one running from the end H and the other from the end G; if the line is a double track each of its wires serves for one track, whereas if the line is a single track they both serve for the same track, one wire for each direction of traffic. The alternating current used for generating the waves is supplied to the distributing lines at a tension of 110 volts; the transformers T raise this to 2 200 volts. The successive discharges between the knobs P-P, which are connected to the secondary winding V of the transformer, (the fundamental condition $r = 4 \frac{L}{C}$ being necessarily realized) produces the necessary oscillating current for giving rise to the electro-magnetic waves in the ether surrounding the track antenna or wire W, and a second wire U — or disengaging antenna —, which we shall describe presently.

Moreover, all the block sections are supplied with the ordinary type of track circuit, comprising a group E of batteries and a relay R; the antennæ W and U are fixed to the armature of the relay and connected to the wave-producer when the relay is excited. It is obvious that under these conditions the antennæ W and U of a section carry current and produce electro-magnetic waves except when the section beyond is occupied by a train; in which case a short-circuit would be formed, the resistance through the train being negligible as compared with that of the relay R. Hence normally, that is to say when the section beyond is clear, the track circuit is completed through the relay R and the antennæ are connected to the wave-producer; on the other hand, if the section beyond is occupied and consequently the track-signal is at « danger », or if any derangement has occurred, the antennæ cease to be in communication with the wave-producer. It is therefore evident that the working of the apparatus is positive.

It is, of course, essential that the antenna W should be insulated from the track; it is preferably placed in the centre of the track running along the middle of the sleepers as shown in figure 8*a*. For this antenna an iron wire 2.9 mm. (0.114 inch) in diameter may be used, and it can be enclosed for protection and insulation in a covering of any convenient form. The maximum length of the antenna that can be charged by a single wave-producer can be measured by miles, and it is therefore evident that the length of the block section depends only on the requirements of the service, and that the system is sufficiently elastic to satisfy practically all the conditions of ordinary practice.

When this antenna, running over the whole length of the block section, is charged, as we have already said, with an oscillating current of very high frequency, it becomes the centre of a series of concentric impulses extending outwards and having a constant radius of influence at all points on the wire. It is a question of a system of electro-magnetic waves which establishes a real non-material connexion, but one that actually exists between the track antenna and the resonator circuit carried on the train with its receiving antenna and its coherer. The field of influence of the waves produced has, of course, a very variable radius, but it is obvious that this depends entirely on the quantity of energy used in the wave-producing circuit.

This range of action must not be overlooked, because it is essential to ensure that a train running on one track should

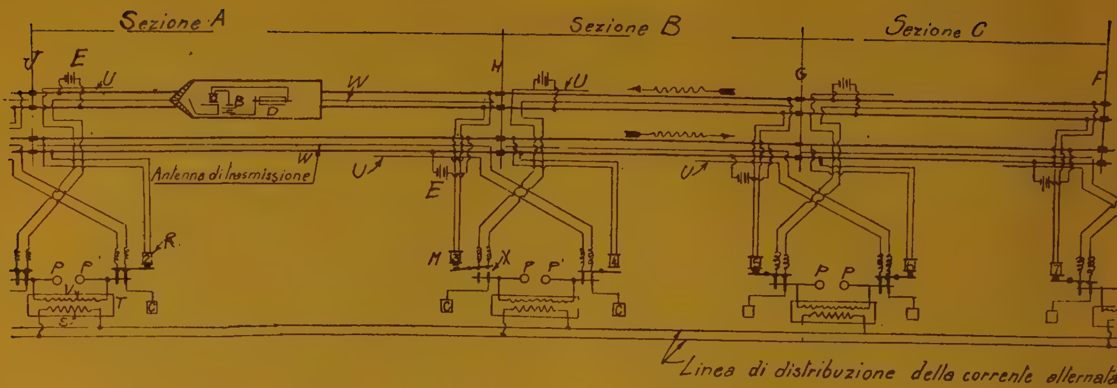


Fig. 8*a*.

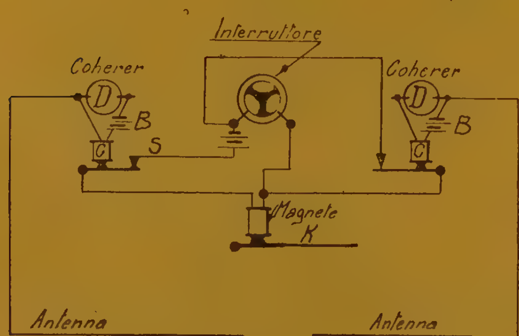


Fig. 8*b*.

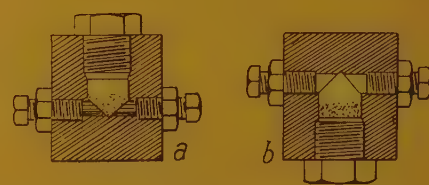


Fig. 8*c*.

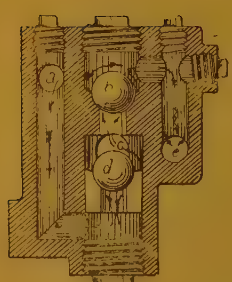


Fig. 8*d*.

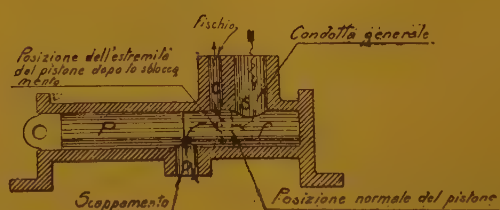


Fig. 8*f*.

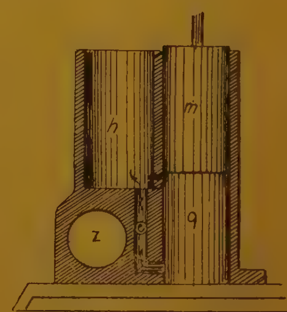


Fig. 8*e*.

Figs. 8*a* to 8*f*. — Perry-Prentice cab-signalling apparatus.

Explanation of Italian terms: Sezione A... B... C... = Section A... B... C... — Antenna di trasmissione = Transmission antenna. — Linea di distribuzione della corrente alternata = Line supplying alternating current. — Coherer = Coherer. — Interruttore = Switch. — Magnete = Solenoid. — Antenna = Antenna. — Condotta generale = Train-pipe. — Posizione normale del pistone = Normal position of the piston. — Posizione dell'estremita del pistone dopo lo sbloccamento = Extreme position of the piston after the line has been cleared. — Scappamento = Exhaust. — Fischio = Whistle.

not receive the indication intended for a train running on the other track; and, moreover, that a train running in one direction should not be influenced by the action of a wave intended for another train running in the opposite direction; for this reason the dimensions of the wave-producer are so chosen as to eliminate any risk of this occurring.

The second group of apparatus of the Perry-Prentice system, the group installed on the train, comprises, apart from the controlling or automatic stopping gear, a local circuit (fig. 8*b*) passing through two coherers (fig. 8*c*) to which are attached two horizontal antennæ arranged parallel to the longitudinal axis of the locomotive at a suitably selected point about 20 cm. (8 inches) above the rail level.

The waves sent out by the wire W act on one of the antennæ making the corresponding coherer D a good conductor; similarly the waves sent out by the disengaging wire U make the coherer D' of the second antenna a good conductor. The disengaging antenna U is arranged parallel to the wave-wire W over a short length, starting from the end of each block section; we shall explain later the functions and working of this disengaging antenna, by tracing the running of the train through the block sections shown in figure 8*a*. The brake-operating apparatus, or automatic stopping gear, consists, in its complete form, of the following parts (figs. 8*a* to 8*e*) :

1° A steam-pump with its piston, the crosshead of which is in one piece with a rack, gearing with a pinion, which causes the coherers to rotate; these make a half-revolution for each stroke of the pump piston, thus occupying two different positions (fig. 8*c*). In the first of these positions the coherers come under the influence of the waves as good conductors of current and the circuit is closed; in the second, even under the influence of the waves, the circuit is interrupted;

2° A horizontal oil-pump;

3° A connecting-rod, which couples the piston of the oil-pump to that of the steam-pump; this connecting-rod is coupled at one end to the piston of the oil-pump whereas the other end remains free to rise or fall in such manner that at the end of its up-stroke it engages with the piston of the steam-pump, and the two pumps work together; on the other hand at the end of its down-stroke the pumps are not coupled. Under normal conditions this connecting-rod takes up two positions according to the movement of the piston of the steam-pump; the apparatus being so arranged that when this piston makes a stroke the coherers are in the position corresponding to maximum conductivity and the electro-magnet circuit is closed; the armature K is then attracted and the end of the connecting-rod may, by means of an arrangement of cams, be made to engage with the crosshead of the steam-pump. The pumps are thus coupled at the end of a forward stroke of the piston; it is during the return stroke of the piston that the oil-pump is brought into action and makes the two forward and backward strokes.

Now let us suppose the wave-production to stop. In this case the coherers no longer become good conductors and the exciting circuit of the electro-magnet is no longer closed; consequently the oil-pump ceases to work;

4° An oil reservoir and a cylinder in which a piston works vertically; while the horizontal oil-pump is driven by the steam-pump the oil, in the two periods corresponding to the two strokes of the piston of the oil-pump, is driven back from the cylindrical reservoir into the

cylinder in such manner that the piston of the latter may be retained in its upper limiting position. It is evident that during the period for which the oil pump is not working, corresponding to the forward stroke of the steam-pump, the piston of the vertical cylinder should, owing to its weight and under the action of forces which, as we shall explain later, act on it, return the oil to the reservoir; but the overflow, the dimensions of the vertical cylinder and the speed of the pump are so adjusted that the piston is, so to speak, maintained steadily in its extreme upper position, only making very short movements during the period of time necessary for the oil-pump to force oil into the cylinder. This time, moreover, is very short because the steam-pump makes one stroke every two seconds without stopping, and consequently the piston of the vertical cylinder may be considered, under normal conditions, to be practically stationary.

If on the other hand the oil-pump were to stop working the piston would come down little by little, under the action of the piston of another cylinder to which it is connected, as the oil below is returned to the cylinder in connexion with the reservoir. Actually, amongst the details of the controlling apparatus, there is also a cylinder communicating with the brake train-pipe, with the warning whistle, and with the exhaust; in this cylinder there is a piston which can move to and fro and uncover the port of the train-pipe putting it into communication with the whistle-pipe and the exhaust, when the pressure of the compressed air, which acts continuously on one of its faces, no longer acts in opposition to the balancing effect of the piston of the vertical cylinder. Of course this action is not instantaneous, but it takes place gradually, as the oil is pushed out of the vertical cylinder into the reservoir, and the working of the apparatus is such that the driver first of all receives a warning by the whistle, and, not until a little after the whistle has blown, does the gradual application of the brakes begin. It must be noted that the working depends entirely on the adjustment of this apparatus, so that, immediately after the waves have ceased to pass, the piston of the steam-pump makes one forward stroke; otherwise it might happen that the apparatus would remain continuously at work.

The inventors, moreover, have sought to modify the apparatus in such manner that the driver can release the brakes, even when waves are not being produced. To do this it is merely necessary to pull over a lever, the end of which engages with the rod of the piston P only when the latter is in its extreme position to the left as shown in figure 8*f*; this cannot happen if the brakes have not worked; the movement of the lever allows the piston P to move until it has closed the exhaust port, whereas the port connecting to the whistle-pipe remains full open, because the return stroke of the piston P, could only be completed if the oil-pump again began to work, and consequently if the waves were again produced.

Notwithstanding this, so long as the driver continues to receive the warning of the whistle until the line is cleared he should continue to run with caution. In fact when the wave-production ceases, the piston P is displaced and interrupts the circuit of the electro-magnet by means of a mercury cut-out; the operation by the driver of the lever for taking off the brakes does not allow this cut-out to be closed, otherwise the piston P could complete its return stroke and no further warning could be given for running with caution. However, when the wave-pro-

duction again begins, although the coherer D again becomes a good conductor the circuit is open, and, in order to close it, it is first of all necessary to allow the piston P to make its return stroke, which is possible if the electro-magnet is otherwise excited. With this object a shunt circuit is used, which is closed by the action of the coherer D' which has been rendered a good conductor by the waves thrown out by the antenna U; it is on account of performing this function that the wire U is given the name of the unlocking antenna.

Space does not permit us to enter into greater detail of this apparatus; but it is doubtless evident that, even leaving out of question the general idea on which it is based, it shows many advantages and chiefly :

1° A normally closed circuit and consequently essentially positive working;

2° Gentle and progressive application of the brakes;

3° Continuous warning for running with caution during the whole time necessary for giving the indication of line clear;

4° May be substituted for the automatic block system.

It must, however, be noted that the safety of working of the system is always dependent on the use of numerous batteries; actually these run the risk of becoming run down when they are placed on the ground and of becoming polarized when they are placed on the locomotive. Moreover, the installation of such a system on a large scale, would, without doubt, be very costly and the expense for its maintenance would also be very high, particularly on account of the delicate nature of the apparatus used on the track, such as the transformers, the condensers, etc.

Finally the system has certain other disadvantages; for example it does not appear that provision has been made for the case of trains running on a track in a direction opposite to the usual direction of running; and it does not appear to be certain that the apparatus would work quite regularly in the case of atmospheric disturbances.

The Belgian State Railway made trials in 1904 of an arrangement invented by the Belgian Vital and the Italian Guarini which is, in principle, exactly similar to the Prentice apparatus, because its working is also based on the use of electromagnetic relationship; the two appliances only differ from each other in certain constructional details.

In this system a high-frequency current flows through a wire placed alongside the line; a circuit comprising a solenoid carried on the locomotive receives the alternating current from the field produced by the current when the line is clear, in such manner that the variation in this flow gives rise in the circuit to electro-magnetic forces and to alternating currents. A very sensitive relay is arranged in the same circuit with the solenoid, the armature of which closes when it is attracted, a local secondary circuit excites an electro-magnet; the armature of which operates a visual or audible signal which repeats the indications of the track-signals to the driver.

The « danger » condition is evidenced by the reduction of the alternating current to a minimum; with this object wherever a signal is placed the line wire has two alternative circuits : the one works normally parallel to the rails, and the other is a shunt. When the signal stands at « danger » a switch sends the primary current through the shunt circuit in such manner as to reduce the flow in the solenoid circuit on the locomotive almost to zero.

Even after allowing for the same objections as those raised to the Perry-Prentice system, it is very evident that the most delicate portion of the apparatus is the relay for detecting the waves, the armature of which closes the secondary circuit; in fact it must be of extreme sensitivity on account of the small amount of energy available; this has prevented a suitable relay from being found up to the present for the work to be done in the locomotive cab.

The future alone will show whether the work of Messrs. Kapp & Kramer, inventors of the system known under the name of the Railophone will enable this very difficult problem of the repetition of signals to be solved in a really practical manner; in fact the essential and original part of the invention of Messrs. Kapp & Kramer consists in the extremely sensitive KK relay, constructed in such manner as to be affected only by the frequency for which it has been adjusted.

To sum up : all the systems of this kind encounter two important difficulties :

1° *The necessity for the constant maintenance of a high-tension and high-frequency current over the whole length of the lines;*

2° *The construction of a relay, which, not being too delicate, shall be sufficiently sensitive, and which can be adjusted so that it is affected only by the frequency adopted for the primary current.*

It is not impossible that by research and improvements in wireless telegraphy and in the technology of corresponding appliances success may some day be attained in the solution of the problem of repeating signals; but at present one must have no illusions as to the practical value of any system based on wireless telegraphy.

We shall conclude this chapter with a summary of the repeating system based on the use of diamagnetic rails of manganese steel, known under the name of *The Horn and Crane Automatic Stop*. The diagram (fig. 9) shows the installation of the fixed portion of the arrangement on the track. In one of the track-rails, and at suitably selected places near to stop signals, short lengths of manganese

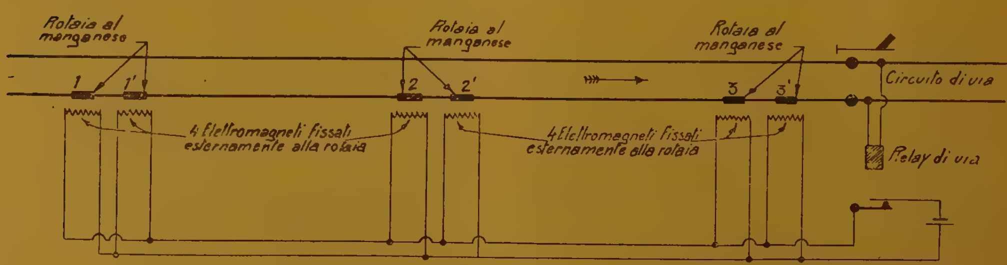


Fig. 9. — The « Horn & Crane » cab-signalling apparatus.

Explanation of Italian terms : Rotaia al manganese = Manganese steel rail. — 4 Elettromagneti fissati esternamente alla rotaia = 4 fixed electro-magnets outside the rail — Relay di via = Track-relay. — Circuito di via = Track-circuit.

steel rail are arranged having a length of 6 feet each and consisting of 88 % iron with 12 % manganese. At each of these places there are also arranged four electro-magnets which are only excited when the section beyond is clear. An electro-magnet is suspended laterally from the locomotive frame and works in

conjunction with the fixed electro-magnets on the track; this electro-magnet is provided with a bi-polar core, one pole of which is normally attracted in such manner as to remain in its extreme lower position in consequence of the action of gravity and of the magnetic attraction produced by the ordinary steel rails; the attraction of this pole of the core causes the brake valve to remain closed.

The arrangement works in the following manner : the core of the electro-magnet, carried on the locomotive, when it is in its lowest position is about one inch above the rail level and on the outside of the track; the coil of the electro-magnet is continuously excited by a local circuit, which is kept closed, derived from a battery carried in the cab of the locomotive.

The magnetic attraction between one of the poles of this core and the ordinary rails produces a rotational movement of the electro-magnet from the outside towards the inside of the track against the resistance of a spring; it is on account of this movement of rotation that the contacts controlling the position of a valve on the main train-pipe remain normally closed. When on the other hand, the locomotive runs over a manganese steel rail, the movable electro-magnet is no longer attracted and consequently through the action of the spring it is given a movement of rotation from the inside towards the outside of the track, which causes the opening of the circuit controlling the brake-valve. Moreover, as we have already stated, the armature of the electro-magnet is supplied with a second pole, which is attracted by the electro-magnets carried on the track when these are excited, that is to say when the section beyond is clear. In this case the action of the spring, which tends to produce a movement of rotation of the electro-magnet towards the outside of the track, is again balanced; a local circuit on the locomotive, shunted from the circuit controlled by the other pole of the armature which actuates the brake-valve, then remains closed. In this manner it is possible to prevent the effects of the rotation of the electro-magnet when the locomotive runs over the end of a manganese steel rail.

The portion of the appliance carried on the locomotive consists of a battery, a maximum cut-out and an electro-magnet actuating a valve admitting compressed air to the brake cylinder; this electro-magnet is controlled by the two poles of the movable electro-magnet.

These parts work in the following manner : when a locomotive runs over the first manganese rail, if the section to which the track signal refers is occupied, the electro-magnet mentioned is demagnetised and the valve admits compressed air to the brake cylinder; this in turn actuates a second valve arranged on the brake train-pipe and the whole is so arranged as to stop the application of the brake at the end of a previously determined period of time. This provision enables the apparatus to play the part also of a speed-reducing gear. Actually the brake cylinder is synchronized with the driving cylinders; consequently the apparatus has not the time necessary to stop the application of the brake until after the speed had been reduced. With this object the manganese steel rail sections are suitably arranged at a distance of about 250 to 500 feet from each other; furthermore the sections 3-3' are shorter then the sections 2-2', and these are themselves shorter than the sections 1-1'. In this manner it is ensured that the speed shall always be reduced on approaching the danger zone. If for example, the driver after having passed section 1 has

reduced the speed before running through section 1' the synchronized cylinder may stop the application of the brakes; but if, on the other hand, the speed has not been sufficiently reduced, the cylinder will not have time to act and the automatic application of the brakes will continue. The sections 2-2', 3-3', represent obstacles of continuously increasing difficulty during the running of the train towards the danger point for they prevent any acceleration between one series of sections of manganese rail and the series beyond it.

It may sometimes happen, as for example at crossings, that it is necessary to use manganese steel rails in order to reduce wear; in this case, in order that the system may still work, it is necessary to fit auxiliary electro-magnets on the locomotive shunted from the circuit of the main electro-magnet; this shunt is normally interrupted. But if alongside the sections of manganese steel rails, which do not form part of the cab-signalling system, steel bars of a suitable length are laid, these will act on the poles of the auxiliary electro-magnets and close the shunt circuit before the main circuit has been interrupted.

CHAPTER VII.

Conclusions relating to cab-signals on locomotives.

The programme of the Italian State Railways

From the examination which we have made of the principal appliances for repeating fixed track-signals in the locomotive cab it follows that these may be grouped in two main classes. The first is based on the following principles : *the repeating of all fixed track-signals and of their indications; automatic working of the brakes and recording of omissions on the part of the driver;* the second, on the other hand, is based on *the simple repeating of some or of all the signals accompanied by recording the omissions of the driver or not, but without any automatic application of the brakes.*

On the very controversial question of the automatic application of the brakes we think that *the apparatus which is confined to repeating the indications given by the track-signals, may work in parallel with the attention of the driver, so that the combination of the probabilities of error in each of the two factors may give a lower total probability; on the other hand, the apparatus fitted with automatic brake-applying gear tends to exclude the human factor by substituting the probability of the error due to the apparatus for that due to the driver, which latter might be the lower.*

There are, moreover, some practical difficulties still encountered in the automatic working of the brakes.

Not all trains are provided with continuous brakes and even though they should be so fitted it happens that on nearly all railway systems different types of brakes are in use. Moreover, the problem is difficult of solution if gradual application of the brakes is to be obtained, at all speeds of the train, in such manner as to avoid dangerous shocks to the passengers and stresses which would prove destructive to the rolling-stock. It must also be noted that experience with the chief repeating systems comprising automatic braking has shown that cases frequently arise of incorrect application of the brakes owing to many causes, such as the presence on the track of heaps of cinders or of clinker.

Finally the direct operation of the brakes by the driver enables him to vary the speed of the train according to the arrangements of the track-signals on the

one hand, and the conditions of the track on the other hand, in the most satisfactory way. With regard to this, attention may be drawn to what frequently happens in all signalling systems : that is to say, that the driver receives warning of « danger » at the distant signal, and that after passing it the home signal is pulled off and gives him the indication « line clear ». Objection might be raised that in this case the arrangement could be so devised as to enable the driver to prevent, or annul, the action of the brake : but it must be remembered that if this were done it would merely result in an inversion of the risks of danger arising from the possible inattention of the driver.

To sum up, it must be recognised that it is necessary to guard against the possibility, which is of somewhat frequent occurrence, that the driver may not see the indications given by the signals, and for this reason to instal an effective system of cab-signalling; but we have however the right to assume that he will obey the indications given to him.

It is by admitting the possibility of inattention on the part of the driver, and as a safeguard against this possibility, that some administrations have adopted automatic working of the brakes; but it appears to us that this does not afford the absolute security of working that is desired, because this measure involves all the other disadvantages that have been mentioned above, amongst which the most serious is the reduction in the attention given by the driver to the track-signals.

With regard to the class of track-signals which should be repeated as cab-signals it is evident that the reply to this question depends directly on the method adopted for solving the question of automatic braking.

In fact, if we confine ourselves exclusively to the simple repetition of the signals, it appears practically sufficient to repeat the distant signal only, for, according to its indication, the driver will generally find no difficulty in observing the corresponding home signal nor in obeying the indication which it gives him; it is moreover possible, by repeating the distant signal only, to avoid many complications in the construction and maintenance of the apparatus. Finally, it is evident that it is not sufficient to give warning on approaching a distant signal; but it is necessary to repeat its indication, whether « line-clear » or « danger », as it may sometimes happen that the driver has not had time himself to observe the track-signal.

On the other hand, if it is desired to add the automatic action of the brake to repeating the signals, it appears advisable, with the object of avoiding a portion of the disadvantages mentioned, to adopt the repeating either to the distant signal or of the stop signal and to provide at the same time for each of the two classes of signals respectively by slowing or stopping by means of the brakes.

On the whole it would appear that the best course is to adopt those *appliances which are limited to repeating as cab-signals the indications of the distant signals only, without any form of automatic braking. Of course, it would be necessary to require that a perfect guarantee of the working should be ensured, and that it should in all cases be positive, in order that any failure or derangement of the apparatus, or uncertainty of the position of the track-signal, should show as « danger » on the cab-signal.*

What are the methods by which this repeating can be ensured?

It is usually done by audible methods; as on the Belgian State Railways, the

Great Central Railway, the Great Eastern Railway, the Great Western Railway, and the North Staffordshire Railway. Sometimes, on the other hand, it is done by visual methods, as for example on the Southern Railway System of the United States of America; sometimes, again, it is done by visual and audible methods combined in some way; as on the London & South Western Railway, North Eastern Railway, New South Wales Government Railways and Roumanian State Railways.

In this last case attempts are generally made, by the use of the two systems, to attract the attention of the driver more powerfully when the track-signals stand at « danger ». In fact the idea of effecting the repeating by visual signals has up to the present been looked on by technical men with a dislike as great as it is injustifiable. In fact, with a view to preventing any distracting of the attention of the driver, it has been almost unanimously held that audible methods are the most suitable because they attract the attention of the driver while allowing him freedom to observe the track-signals which it would doubtless have been impossible to do when using a visual cab-signal.

It was, moreover, thought advantageous to repeat the signals to all the employees on the train at the same time as to the driver. To do this a very powerful audible signal was required, as for example powerful sirens, or compressed air whistles, the noise from which would be clearly perceptible even in the rear van of the train or even on a bank-engine at the rear of the train. In order to meet this condition some administrations have adopted very powerful audible signals, but, on account of the frequency with which the signals were repeated, the system was soon found to be a source of annoyance to the passengers and it also raised protests from the inhabitants living alongside the railway. The latter heard the whistles much better than did the train staff, who, notwithstanding the measures taken, were unable to hear the signals at all under certain specially bad atmospheric conditions. It is, perhaps, for this reason that audible signals have not come into general use; and experience has shown that they cannot satisfy all the conditions that occur in practice.

Quite recently the visual signals have attracted more and more attention from technical people. In fact it must be recognised that there is but one alternative: *if it is absolutely necessary that the driver should keep a look-out on the track the principle of cab-signalling cannot be accepted, but, on the contrary, if the necessity for assisting the attention of the driver is recognised — and we have already shown with regard to this that this is indisputable — then this assistance must be given in the most complete and most effective manner.* In this second case we think that there is nothing more effective than to place the visual repetition of the track-signals immediately under the eyes of the driver. If by chance it should happen, as we have shown above, that the driver does not succeed in obtaining the indications of the track-signals or of the position of the signals themselves that is to say that he has missed observing the signal, what would be the value of an audible signal to him? This may be produced at the moment when his attention is already engaged in other matters that may perhaps be very important and which it would be dangerous or at any rate irregular for him to neglect, particularly when the signals stand at « line-clear ». If, on the other hand, the signals are at « danger » it is evident that it is necessary to attract the attention of the driver

by more powerful means; we consider that it is advisable for this purpose to combine the visual with the audible cab-signal with the one object of immediately attracting the eye of the driver to the visual signal in such manner that, on seeing the « danger » indication, he can himself keep a look-out on the track if possible. *It follows from this that audible repeating is an auxiliary duplication of visual repeating; this should be preferred on principle, because it appeals to the sense of sight which is doubtless much more sensitive and better educated than that of hearing, and is a sense the activity of which does not become reduced as the driver begins to get tired.*

For this reason we prefer the visual repetition both when the signal is at « line clear » and when it is at « danger » on the condition that it remains visible for a sufficient length of time; moreover, the visual cab-signal in the case of a signal at « danger » should be accompanied by an audible cab-signal, the whistle of which can be stopped by the driver.

From what we have just said it is evident that the problem that we have briefly treated is very important for the safety of railway working; but that a large number of difficulties are encountered in its solution.

Much progress has been made towards a practical solution thanks to the persistent efforts of the railway administrations, mentioned above, and of many others of whom our distinguished colleague, Mr. Ferdinand Maison, the reporter for France, will speak. It is not impossible that success will be found in this direction some day, but, to the present, it must be recognised that real practical success has not yet been obtained.

The Italian State Railways having realized the great importance of this subject undertook investigations the result of which is summed up in the following statement, which comprises the technical conditions that the repetition of track signals as cab-signals on locomotives, in our opinion, should satisfy :

1° The apparatus should repeat in the locomotive cab the indications of distant signals. It is not required, nor is it considered desirable, that the apparatus should comprise automatic braking. The repeating should be visual both for « line clear » and for « danger » and should remain visible for a sufficient length of time; it should, moreover, be audible in the case of a signal at « danger » and it should be possible for the driver to stop the audible warning. The apparatus should be so arranged as to set itself automatically to normal position each time, after it has been operated, in readiness for giving a fresh warning;

2° It is necessary that the apparatus should be so arranged that any failure or derangement of the essential parts of the system and of their electric connexions, if these exist, or any uncertainty as to the indications given by the track-signal should cause the cab-signal on the locomotive to indicate « danger »;

3° The apparatus should be so constructed that it can be used equally well in the open air, in tunnels and on bridges; it should also be capable of being adapted both to lines worked by steam and to lines worked electrically, either by continuous or alternating current;

4° It is essential that the apparatus can be easily adapted both to single tracks and to double tracks; in the latter case it is sufficient to arrange for the running of the trains in one direction only on each track. It is also necessary that the system should be capable of being adapt-

ed to steam or electric locomotives whether running in forward gear or in reverse gear when hauling traffic;

5° It is necessary that the details of the apparatus should keep clear of the construction gauge of the track and the loading-gauge of the train in such manner that the parts on the track may not be shifted or damaged by parts of the locomotives or rolling-stock;

6° Whatever the type of apparatus may be, whether mechanical, electrical, electro-mechanical or electro-magnetic, it should be of simple and strong construction and completely protected from bad weather. The essential parts of the arrangement should be combined and protected in such manner as to avoid risk of damage. The contact between the parts carried on the locomotive and those on the track should be ensured even at very high speeds and it must not be made inoperative either by the ordinary vibrations of the locomotive when running, or by the wear of the track or of parts of the locomotive. In the case of mechanical appliances the parts which ensure contact should be so arranged as to ensure perfectly complete and regular working of the apparatus for a sufficient length of time. The fixed part of the apparatus, arranged in the track, which is connected to the signal should not cause interference with the proper working of the signal nor should it add appreciably to the strain on the transmission gear of the signal. If, on the other hand, it is a question of electrical apparatus, preference will be given to arrangements in which the circuit is normally closed;

7° It is not made an absolute condition that the apparatus should be recording. Appliances which enable recording to be performed easily for « line clear » and « danger » on the ordinary tachymetric diagram will be given consideration, as also will records on other diagrams if the locomotives are not fitted with speed-recorders. In this latter case the paper of the recording apparatus should be unrolled proportionately to the distance run by the driving wheels. The audible repetition in the cab of the locomotive may be obtained by using the continuous brake train-pipe, provided that this does not produce automatic stoppage of the train.

It should be noted that the statement of which we have given a *résumé* is not put forward as absolutely definite; it might be modified to some extent by the particulars of the results of practical application laid before us. Moreover, it should be remembered that it has been drawn up with the object of serving as a guide to inventors regarding the conditions to be met. As the result of discussions held with the firms manufacturing these appliances we shall shortly commence comparative trials with the repeating apparatus known under the name of « The Audible Railway Signal » of the Great Western Railway, with the « Syx » electro-mechanical apparatus and with the Augereau radio-telegraphic apparatus. From the results of these trials it may be possible to determine which will be the best direction to follow with the view to obtaining more general and systematic application of cab-signalling.

CHAPTER VIII.

Recording running speeds.

The problem of speed-recording and of indicating the speed to the driver in the cab of the locomotive is also to some extent allied to the problem of cab-signalling. Its importance is so great that it soon attracted the attention of the technical staff, and the question was ra-

pidly solved by the adoption of special appliances either for showing and recording the speed or for showing it only

There was one objection only to these : in fact the principal objection that was made to these appliances was that they were too expensive and that it was feared that their maintenance and the checking of the record-strips might involve expenditure out of proportion with the object in view. But, on the other hand, as against this objection, and in favour of the solution of the problem in the affirmative, it was not properly realized that they might have many definite advantages, both for the safety of the public and for the working of the railways. These advantages may be summed up in the following manner :

1° That the driver can keep strictly to the time-table;

2° That the driver may have greater liberty of action and freedom as he is not under the obligation to be continually determining the speed of the train by means of his watch, or other empirical and rough methods, with the object of keeping his speed to suit the time-table and of enabling him to give almost undivided attention to looking after the locomotive and looking out for the track-signals;

3° That greater safety of working is obtained, for if, by chance, the driver had exceeded the allowable speed on any section of the track, and that consequently the train was run at an excessive and dangerous speed, this would at once be registered by the recording and warning apparatus;

4° That it should be possible to operate the brakes in accordance with the indications of the track-signals and of the repeated signals given in the locomotive cab.

Moreover, if the apparatus at the same time shows and records the speed, which can be easily arranged with nearly all appliances, the following advantages must also be taken into account;

5° That an indisputable record of the responsibility of the driver in the case of accidents due to excessive speed, or produced by violent and irregular application of the brakes, can be obtained;

6° That there should be the possibility of checking, subsequently to the making of the record, the speed of the train at almost any instant and thus ascertaining any error on the part of the driver.

These advantages, as well as others which need not be here discussed, soon prevailed over the objection raised on account of the expense of the installation and of the maintenance of the combined speed-recording and indicating apparatus. Also, when the pressure of public opinion required the recording of speeds as well as the repeating of signals in the cabs of locomotives, these advantages led the chief railway administrations to adopt, or at least to test, such appliances. The problem, which had been accorded a favourable reception in theory, soon passed into the field of practical work and took the form of a search for the best type of apparatus amongst those which the ingenuity of inventors enabled to be submitted to the railway engineers, who gave great attention to the solution of the problem.

In fact the administrations soon found that there were a large number of these appliances, the merits of which required investigation; amongst those which have been tested, or adopted, by the administrations that have replied to our list of questions, we may mention the following:

1° The Flaman speed-recording and warning apparatus;

2° The Hausshaelter speed-recording and warning apparatus;
3° The G. Hasler chrono-tachymeter;
4° The Hasler-Teloc speed-indicator;
5° The Boyer speed-indicator;
6° The Deuta speed-indicator;
7° The Stroudley speed-indicator;
8° The L. G. Netherlands Railways type, speed-indicator;
9° The Sirius speed-indicator;
10° The Deutsche Tachometer Werke speed-indicator;
11° The Klose speed-indicator;
12° The Brühn speed-indicator;
13° Horn speed-indicator;
14° Siemens and Halske speed-indicator;
15° Kalb speed-indicator;
16° Hartmann and Braun speed-indicator;
17° Stone's speed-indicator;
18° Jones speed-indicator;
19° Penta speed-indicator;
20° Brinkmann speed-indicator;

These appliances have been tested on a large scale by almost all the administrations, and are already so well-known that there is no need for us to give a description of them, as this can be easily obtained from the inventors, or from the firms manufacturing the appliances. We shall consequently limit ourselves to giving a brief note on the subject of some of the less well-known of these of which we have received sufficiently complete data.

With regard to the manner in which the problem has been solved it can be stated that the indicating appliances can be classified in the following manner :

a) Speed-indicators in which the inventors have confined themselves exclusively to a visual indication of the speed;

b) Speed-recording and indicating appliances giving a visual indication of the speed combined with a graphic record giving the speeds of the train as closely as possible.

From the technical point of view of the solution of the problem, the systems used for these appliances may be classed in three main groups :

a) Direct-driven speed-indicators amongst which may be mentioned the apparatus or systems of Klose, Horn, Hartmann and Braun, Stroudley, Deuta, Boyer, the L. G. Netherlands Railways type, etc.; they depend chiefly on the utilization of the centrifugal force of rotating masses, solid or liquid, acting against gravity or acting against one or more springs; or they depend on electro-magnetic forces produced by the action of the rotating field of a permanent magnet on a short-circuited movable armature; by this means the angular velocity of a spindle revolving at a speed proportional to the speed of one of the driving axles, that is to say of the train, is measured at each instant; the change proportional to the speed is obtained by means of suitable reducing gear;

b) Speed-indicators working by summation or by combined operations, among which must be mentioned the Hausshaelter, Hasler, Hasler-Teloc, Flaman, etc.; they are based on the principle of measuring the speed of the train by measuring the range of movement of a part of the apparatus in unit time or over unit distance (time base or distance base);

c) Differential speed-indicators in which the speed is determined by means of a differential gear enabling it to be compared with a given speed.

If the direct-driven speed-indicators have the advantage of really showing the speed at any instant and of following rapid changes of speed, on the other hand

they do not lend themselves to recording their readings which are not exact for all speeds, some systems being unable to record low speeds. In addition, these systems have the disadvantage of requiring to be periodically and very frequently adjusted on account of the inevitable wear of the springs.

On the other hand, the speed-indicators that work by « summation » or combined operation have the disadvantage that they can only record a mean speed over a certain length of time or track; it may sometimes happen that the speed undergoes rapid changes and if it is desired that these changes should be made susceptible to the eye and that a record should be obtained agreeing as far as possible with the momentary speed, it is necessary to make these intervals of time or of track as short as possible. If these intervals could be actually reduced to a minimum the apparatus would have the maximum of perfection possible to obtain for its class; but it must be recognised that the principle on which they are based itself prevents the realisation of this ideal, and that any attempt made by the inventors with the object of attaining it renders the apparatus very delicate and costly.

Finally the differential speed-indicator possesses, although in a minor degree nearly all the disadvantages of most of the appliances of the two groups mentioned above; moreover in general the mechanism is somewhat complicated.

CHAPTER IX.

Speed-recording and warning apparatus.

We shall now give a short description of some of the less-known types of apparatus that have been mentioned to us, leaving out those which, owing to their wide use, are sufficiently well-known, such as the Hasler, the Hausshaelter, the Flaman, the Teloc, the Boyer, etc.

The Stroudley speed-indicator. — This apparatus consists essentially of a short cylinder of small diameter in which revolves a wheel carrying paddles and driven from one of the driving wheels of the locomotive; in order therefore to allow of the rotation of the paddle-wheel spindle this passes through a stuffing box carried on one of the ends of the cylinder, and packed with leather washers and carefully turned and lubricated by means of a grease-cup.

On the upper part of the cylinder is placed a reservoir in free communication with the centre of the cylinder at the point opposite to the paddle-wheel spindle, and carrying a glass tube fitted with a suitably graduated scale; this tube is also in free communication with the upper part of the cylinder so that the movement of the paddle wheel can draw water from the reservoir and send it into the tube. If follows that the height of water in the tube is proportional to the number of revolutions per minute of the paddle wheel and consequently to the angular velocity of the driving wheels.

The scale is so graduated as to show the speed in miles per hour or in any other desired unit; the zero of the scale corresponds to the locomotive at rest; slipping of the wheels is shown by the water rising to the top of the indicator.

The apparatus is, moreover, placed in the cab of the locomotive in a suitable position for the driver to be able to see readily whether the locomotive is running at a regular speed.

The L. G. speed-indicator of the Netherlands railways type. — This apparatus resembles the Deuta speed-indicator (1) exactly; it is based on the use of

(1) See *Bulletin of the International Railway Association*, March 1922, p. 552 (Report of Mr. Verdeyen).

a magnetic field, revolving at a speed proportional to that of the driving wheels and consequently to the speed of the train, and of a squirrel-cage armature of very light construction in aluminium and having thin walls.

It is, moreover, of special importance that efforts should be made to render the apparatus independent of the influence of temperature, by means of a special arrangement for compensation for temperature, without which no moving part performs its function properly.

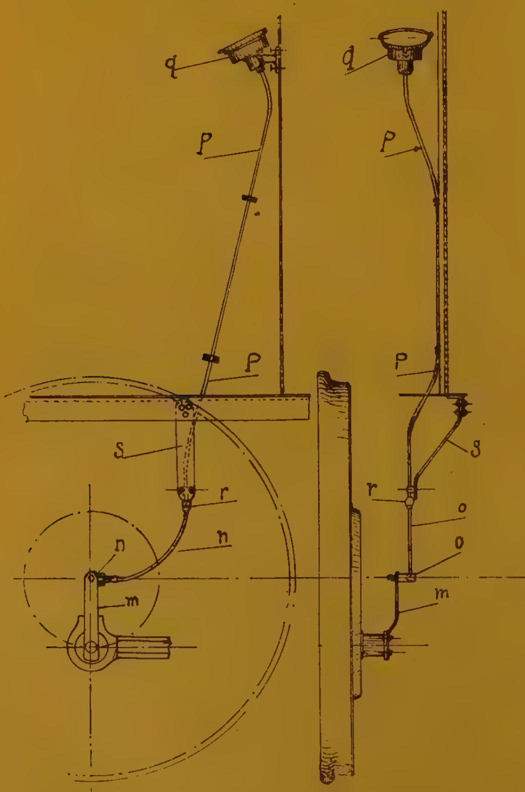


Fig. 10. — L. G. type of speed-indicator with suspended gear-box.

A special method is also provided for transmitting the movement of the driving wheel to the spindle of the electromagnet by means of an arrangement known as the « free-suspension gearbox » which must be used whenever special conditions prevent the ordinary flexible transmission from being used, as for example when the driving axle is too far from the driver's cab, or when it has very great lateral play, or when, in the case of wheels of small diameter, the flexible shaft would come too near to the ground and might consequently run the risk of damage. The use of the gear-box is also advisable because, under difficult working conditions, the proper maintenance of the flexible connexion cannot be depended upon. The gear-box, that has been mentioned, works in the following manner : on the arm *m* of the return crank carried on the driving wheel (fig. 10), or on a flange carried on the axle of a carrying wheel, the gear-box *n* is arranged with the end of its shaft projecting on one side and fixed by a driving screw in such manner that it is at the same height as the centre of the axle of the wheel. A ball-bearing and a casing protecting it from dust enable it to run freely. The driving spindle which projects transversely is attached to a jointed shaft which in turn is connected to the speed-indicator; this shaft is encased from the gear-box in a flexible metal tube *o* which usually has a length of about 550 mm. (21 11/16 inches) and lead to the speed indicator *q* through a fixed pipe *p*. The flexible metal tube easily accomodates itself to the movement of the frame of the locomotive, without exercising any unfavourable influence on the rotational movement of the flexible driving shaft. This freely suspended gear-box, with the rigid shaft driven through the arm fixed to the axle is distinctly better in its arrangement than other driving gears in which the gearing is rigidly connected to the frame of the locomotive.

In fact it has been shown in practice that when the gear-shaft is carried in the

last-mentioned way it is subjected to violent distortion and shock, even though the intermediate part should transmit rotational movement through a flexible or jointed shaft; it follows in such case that the bearings of the spindles are soon damaged, and the gearing suffers in consequence, with the result that the whole drive ceases to work properly.

The free suspension of the gear-box, which was introduced exclusively on electric locomotives, although it could have been used equally well on steam locomotives, has proved capable of standing working conditions for a number of years without requiring special maintenance, and its utility has been proved even under the most difficult conditions.

CHAPTER X.

The recording and indicating of running speeds on the Italian State Railways.

The locomotives on our railway system are not all fitted with speed-indicators. Generally the speed-indicator is fitted on the one hand to express tender-locomotives used for passenger service, and on the other hand to some classes of tender-locomotives and some tank-locomotives used for passenger service, or for goods traffic, on lines having steep gradients, or on light railways.

In the last case we think that the use of the speed-indicator is very valuable when the locomotive is of a class having a short wheel-base with regard to the suspended weight, and when the lines run over are not in the best condition, requiring special supervision and careful checking with a view to preventing the exceeding of the speeds laid down respectively for the locomotive and for the line, it being understood that in the cases quoted these speeds, in excess of the given limits, might prove a real source of danger for the safety of working.

The locomotives for which the application of the speed-indicator is required belong to the types given below; for each of these types the total number of locomotives in the class and the number fitted with the speed-indicating apparatus is given, as well as the service on which they are usually engaged.

Nearly all our speed-indicators belong to the type of apparatus with combined mechanical drive, one of which is effected at a variable speed and the other at constant speed. These appliances are at the same time indicating and speed-recording apparatus and the winding of the paper is proportional to the time. Trials have, moreover, been made of some types of apparatus, giving an indication of the speed only which have been adopted exclusively on electrified lines, where the locomotives run with three-phase alternating current, as is well-known, at speeds that are constant and perfectly determined.

In this case the speed-indicator enables the staff of the locomotive to ascertain the position on heavy gradients, particularly in cases where regeneration of energy is not effected.

It was thought advisable to adopt speed-indicating and recording apparatus in these cases as it would, by means of the speed-indicator diagrams, be possible to determine indisputably the responsibilities of the staff in charge of the locomotive, particularly in case of exceeding the permissible speed, either for the locomotive or for the track. Moreover, the use of a recording apparatus renders it easy to check whether the staff in control of the locomotive follows the regulations, even though these should be of a provisional nature, as may be given from time to time in case of permanent-way slacks, being piloted, etc.

Steam locomotives.

TYPE.	Class.	Number of locomotives fitted with speed-indicators.	Class of service usually performed.
		Locomotives with tenders.	
(0-4-0)	410	25	For goods trains on level lines and in mountainous country.
(0-4-0)	420	135	Ditto.
(0-5-0)	370	144	For goods and passenger trains for through lines with heavy gradients.
(1-2-0)	550	18	For passenger trains on light railways and level country.
(1-3-0)	625	108	For passenger trains on lines having steep gradients and for through goods trains on level country.
(1-3-0)	630	100	For ordinary passenger trains and for mixed fast trains on lines in level country having easy gradients.
(1-3-0)	640	169	Ditto.
(2-3-0)	670	43	For heavy express trains running on ordinary lines.
(1-3-1)	680	151	Ditto.
(1-3-1)	685	106	Ditto.
(2-3-1)	690	33	For heavy express trains running on heavy tracks and over strengthened bridges.
(1-4-0)	745	12	For heavy passenger trains and for goods trains on lines having medium gradients (coast line of the Tyrrhenian Sea).
		Tank-locomotives.	
(0-3-0)	851	206	For passenger trains and for goods trains on light railways in mountainous or hilly country.
(1-3-0)	950	84	Ditto.
(0-3-0)	870	168	For light passenger trains on light railways with light track.
(1-3-1)	910	16	For passenger trains and for goods trains on short runs where the locomotive is not reversed at the ends.
(0-3-0)	980	12	For passenger trains and goods trains on lines worked by ordinary adhesion or by rack.

Electric locomotives.

TYPE.	Class.	Number of locomotives fitted with speed-indicators.	Class of service usually performed.
(1-3-1)	E. 320	5	For passenger trains and for goods trains on lines in level country or with medium gradients.
(1-3-1)	E. 330	16	
(2-3-2)	E. 331	18	
(2-3-2)	E. 332	6	

The administration of the Italian State Railways, owing to the special conditions that prevail over the greater number of lines on its system, and consequently the numerous regulations relating to the running of the locomotives, has decided, in its own interest, and with the object of avoiding as far as possible difficulties of working, to adopt simultaneous speed-recording and speed indicating apparatus.

The examination of the speed-indicator diagrams not only enables the end in view to be attained, but it also enables a check to be kept on the actual running and on the stops shown in the guard's journal.

With this object the locomotive staff is instructed to hand in after each run, the speed-indicator diagram with the running sheet, and has to explain if this is not done.

For the reasons given above, it follows that the expense caused by checking the speed-indicator diagrams, in changing them and in the maintenance of the apparatus, are more than compensated for by preventing damage which might arise from want of observance of the maximum speed limits and of the regulations made with the object of obtaining the greatest possible regularity in the running of the train service.

Even when recording speed-indicators are in use it is not possible or advisable to give up the record taken by the shed foremen and stationmasters, with regard to the time of starting from the shed and the arrival in the station of the locomotive hauling the train, particularly as it happens that the speed-indicators are not started up on the locomotive when it begins its run, that is to say when it leaves the shed, but only a little time before train starts.

Another difficulty is that the station staff is not in the position of knowing what locomotive will be allotted to a train and consequently it cannot know whether it is or is not fitted with a speed-indicator.

We have never used speed-indicators placed on the track. The speed-indicators normally in use on our locomotives are the following:

a) The Hausshælter speed-indicator, types of which have been made by Messrs. Seidel & Naumann of Dresden and by the firm of Hasler of Berne;

b) The Hasler speed-indicator constructed by the firm of Hasler of Berne, which is an improvement on the Hausshælter apparatus. Both of these appliances are at the same time indicating and recording.

For trial there are also nine Flaman

speed-indicators made by the firm of Lamazière et Bunzli of Paris; they have the feature that the movement of the paper is proportional to the distance run, whereas in the Hausshælter and Hasler apparatus the movement is proportional to the time.

We have, in all, on our Railway System 1 173 appliances of the Hausshælter type, 655 of the Hasler type, 1 of the Tel type (indicating only) and 28 of the Deuta Werke type (also only indicating) which have been delivered to us, in the latter case, with German locomotives allotted to us by the commission for reparations due to the war.

The Flaman type has been under trial since 1911, but is has not come into general use on account of its high cost, which doubtless exceeds that of the Hausshælter and Hasler appliances, and also with a view to not increasing the number of types of apparatus used on the railway system which would entail an increase in the store of spare parts.

As we have already stated, the Hausshælter and Hasler speed-indicators do not record or give instantaneous changes of speed; they only record mean speeds.

The hand which shows the speed on the dial moves every six seconds in the Hausshælter type of speed-indicator and every second in the Hasler type of speed-indicator; the distance between two successive points on the line showing the running speed on the diagram is given every three seconds on the Hasler speed-indicator and every twelve seconds on the Hausshælter speed-indicator.

In the Flaman speed-indicator the hand moves every four seconds and the record of speed is made every time that the hand moves.

In Italy there is no law imposing on railway administrations regulations requiring steam or electric trains to be fitted with speed-indicators on the locomotives; the application of these appliances and the selection of the most suitable types is made by our administration, entirely on its own initiative, as the result of a very careful technical examination of the conditions necessary for stability of the locomotives while running, of the features of gradient and level on the lines over which the traffic is run, and of the strength of the structure of the tracks.

APPENDICES.

The following administrations have replied to the detailed list of questions; they are designated below by a number and their initials :

ADMINISTRATIONS.	NUMBER AND INITIALS.
BELGIUM. — Belgian State Railways	1. E. B.
DENMARK. — Danish State Railways	2. E. D.
SPAIN. — Andalusian Railways	3. A.
Spanish Northern Railways	4. N. E.
UNITED STATES OF AMERICA. — Erie Railroad Company	5. E.
Southern Railway System	6. S. R. S.
Baltimore & Ohio Railroad	7. B. & O.
GREAT BRITAIN AND IRELAND. — Great Central Railway	8. G. C.
Great Eastern Railway	9. G. E.
Great Western Railway	10. G. W.
London & South Western Railway	11. L. S. W.
North Eastern Railway	12. N. E.
North Staffordshire Railway	13. N. St.
Midland Great Western Railway	14. M. G. W.
AUSTRALIA. — New South Wales Government Railway	15. N. S. W.
INDIAN EMPIRE. — North Western Railway	16. N. W.
Bombay, Baroda & Central India Railway	17. B. B. C.
GREECE. — Hellenic Railways	18. E. G.
Piræus, Athens, Peloponnesus Railways	19. P. A. P.
NORWAY. — Norwegian State Railways	20. E. N.
HOLLAND. — Netherland State Railways	21. E. P. B.
ROUMANIA. — Roumanian State Railways	22. E. R.
SWEDEN. — Swedish State Railways	23. E. S.
Bergslager Railways	24. B.
Halmstad-Nässjö Railways	25. H. N.
SWITZERLAND. — Swiss Federal Railways	26. F.
YUGO-SLAVIA. — Railways of the Serbian, Croatian and Slovene Kingdom	27. S. C. S.

APPENDIX A.

Repeating and recording the track signals on the locomotive.

QUESTION 1. — *Different systems already used or tried. Results obtained. The indications of which signals do you consider it necessary to repeat on the locomotive?*

Belgium.

1. *E. B.* — All absolute stop signals and their distant signals.

United States of America.

5. *E.* — The Erie Railroad has not adopted automatic control for trains.

6. *S. R. S.* — Visual signals which give warning for caution and for absolute stop signals.

Great Britain and Ireland.

8. *G. C.* — We have not tried any system for repeating and recording the track-signals in the cab of the locomotive. It is not thought necessary or desirable to repeat the track-signals on the locomotive.

9. *G. E.* — We have made experiments with the Syx system. The distant signals.

10. *G. W.* — Only distant signals.

11. *L. S. W.* — Distant and home signals.

12. *N. E.* — All signals covering entry to the section.

13. *N. St.* — Particularly for distant signals at line-clear and at danger.

Australia.

15. *N. S. W.* — In the case of ordinary railways for the indication of the distant signal.

Holland.

21. *E. P. B.* — The repeating of track-signals has only been carried out experimentally for a few years.

Roumania.

22. *E. R.* — We have not made experiments with any system. The stop signals.

Sweden.

23. *E. S.* — There is no repetition of signals on our locomotives.

On some electric motor vehicles (continuous current) apparatus is fitted for the automatic application of the brake. The fixed apparatus on the track is arranged at the side of the rails on a post at a distance of about 50 m. from the station signal-post. The fixed apparatus is controlled by the position of the signal. After application of the brake the current to the motors is cut off.

QUESTION 2. — *What general conditions have to be satisfied in this repetition of the track signals on the locomotive?*

Belgium.

1. *E. B.* — *a*) To give, when the distant signal is at « danger », and 200 m. (220 yards) before the signal, a whistle warning which can only be stopped by the driver taking action.

b) To give a different whistle warning when the distant signal is at « line-clear ».

c) To apply the brakes automatically and gradually at the distant signal if the driver does not take action to silence the whistle indicating « danger » (stop).

d) To apply the brakes automatically when the home signal is run past at « danger ».

United States of America.

6. *S. R. S.* — The greatest possible safety in working obtainable and mechanical stoppage in case of any failure of the apparatus.

Great Britain and Ireland.

8. *G. C.* — We are at present using the Reliostop system by which an audible warning

is given on the locomotive on approaching a distant signal. It is only a question of a warning which is given in any event whether the signal is at « danger » or at « line-clear ».

9. *G. E.* — When the signal is at « line-clear » a short ring on the bell is given on the locomotive. When the signal is at « danger » a whistle sounds continuously and the brakes are applied automatically. This application of the brakes can be stopped in the case of a distant signal, but cannot be interfered with in the case of stop signals.

10. *G. W.* — The signals for « line-clear » as well as those for danger should be repeated audibly and it should be possible to distinguish them readily by their sound, whilst when the « danger » signal warning is given, there should be an automatic application of the brake. In case of failure of any part of the apparatus the « danger » signal should always be given.

11. *L. S. W.* — The position of the lever in the signal cabin, the track-signal and the indication given in the locomotive cab, should correspond exactly in a perfectly definite manner. The indicator should be so placed in the locomotive cab as not to interfere with the view of the driver.

12. *N. E.* — Signals repeated directly on the locomotive should give the driver, as far as possible, the same indication and as far before the signal as would be given by his seeing the track-signal which is repeated.

13. *N. St.* — With the Syx system, the audible signal given in the locomotive cab should be sufficiently loud, and should last for a sufficiently long time to attract the attention of the driver.

Australia.

15. *N. S. W.* — Any failure whatever of the apparatus should always produce a safe indication.

Holland.

21. *E. P. B.* — The general condition to be fulfilled in the repeating of cab signals will be : to stop the train before reaching a signal at « danger » provided that the working is recorded and that the driver can, if he has seen the signal in time, prevent the recorder from working, so that there may be a check on the attention given by the driver. Warning to the driver at some distance before a stop signal would distract the attention of the driver.

Roumania.

22. *E. R.* — Simplicity from the point of view of construction; certainty of working and clearness in the signals.

QUESTION 3. — *In what way should the apparatus inform the driver of the position of the signal past which he is running? By a visible signal, or by an audible one, or by one which is audible as well as visible?*

Belgium.

1. *E. B.* — By an audible signal.

United States of America.

6. *S. R. S.* — By a visible signal and by the application of the brakes until the train has been stopped, or by the application of the brakes, when the speed of the train exceeds a pre-determined maximum, which continues until the speed has been reduced to this maximum.

Great Britain and Ireland.

8. *G. C.* — By an audible warning on the locomotive on approaching a distant signal.

9. *G. E.* — By an audible warning, either indicating « line-clear » or indicating « danger », supplemented by application of the brakes in the latter case.

10. *G. W.* — By an audible signal accompanied by gradual application of the brake when the signal indicates « danger ».

11. *L. S. W.* — For both forms of repetition, visual and audible signals.

12. *N. E.* — This question should have been worked as follows : «... to warn the driver of the indication given by the signal which he is approaching ».

A driver has no right to pass a signal when he does not know the position of it.

The indication given in the locomotive cab should correspond to that of the track-signal by means of a visual signal and it should be possible for it to change to an audible signal in order to draw attention to a change in the visual signal.

13. *N. St.* — With the electro-mechanical Syx apparatus, the signal given is audible.

Australia.

15. *N. S. W.* — By an audible signal, supplemented, if thought advisable, by a visual signal.

Holland.

21. *E. P. B.* — It does not appear to us to be useful to warn the driver.

Roumania.

22. *E. R.* — Visual signal accompanied by an audible signal.

QUESTION 4. — *What apparatus have you adopted? Which kind have you tried and which are you trying at present?*

What apparatus have you tried and afterwards discarded, and for what reasons?

Amongst the apparatus tried, to which have you given the preference and for what reasons? Have you the intention of making any alteration to the chosen apparatus and for what object?

Do you expect to bring it into general use?

In particular, please state, in the case of each system :

Belgium.

1. *E. B.* — No type of apparatus has been adopted up to the present.

United States of America.

6. *S. R. S.* — No apparatus has been adopted.

Great Britain and Ireland.

8. *G. C.* — The apparatus adopted by this company is the Reliostop.

9. *G. E.* — We have adopted the Syx apparatus constructed by the Sykes Interlocking Signal Company, Clapham, London, S. W. We do not expect to adopt it generally.

10. *G. W.* — We have made experiments with audible signals which can be distinguished perfectly by their sound according to whether they repeat an indication of « line-clear » or of « danger » with automatic application of the brake. We do not expect to make any change in it.

11. *L. S. W.* — On the Waterloo and City electric line we have had a system consisting of a contact-treadle placed alongside the rails with a brush-contact on a motor, the working of which depends on the signal in such manner that, if the signal shows stop and the train runs over the treadle, the current is cut off. If the signal on the train shows « line-clear » the contact with the treadle does not interrupt the current on the train. We have made experiments with the following appliances : 1) cab-signalling by the wireless-telegraph-Prentice system; 2) many mechanical systems with treadles on the ground and brushes or striking levers carried on the locomotive; 3) explosions of detonators giving optical or audible signals in the cab of the locomotive; 4) luminous indication in foggy weather. In general the appliances in classes 1) and 2) have been abandoned on account of : 1° excessive cost; 2° uncertainty of action of the ground-apparatus which became damaged by the trains in running over it. Classes 3) and 4) are at present under trial.

12. *N. E.* — No type of apparatus has been officially adopted so far. Two systems have been subjected to trial; mechanical and electrical. No system has been tried and then abandoned. The question of preference depends entirely on the conditions that it is desired the apparatus should fulfil. If it is necessary to give complete indication preference will be given to the electric apparatus. If, on the other hand, it is only a question of checking the trains the mechanical apparatus appears more suitable on account of its simplicity and of its ease of maintenance. The question of the general use of the apparatus

depends upon the report of a special Government Committee, and this report has not yet been made.

13. *N. St.* — No apparatus has been adopted by the North Staffordshire Railway. A special trial has been made of the Syx apparatus for a distant signal and with a locomotive specially equipped for this object. The trials proved completely satisfactory, but the apparatus was given up as its adoption, leaving the system out of account, was not considered. We do not expect to adopt it generally.

Australia.

15. *N. S. W.* — We have adopted the apparatus introduced by the English Great Western Railway. No apparatus has been tried and subsequently abandoned. A trial will be made with the electro-mechanical Syx system for checking the trains. It is intended to adopt one of the two above-named systems generally.

Holland.

21. *E. P. B.* — We have tried the apparatus of the English Great Western system and of the van Braam system. We have given up the van Braam apparatus because it did not work without failure, and the Great Western apparatus because a warning appliance was not considered necessary, particularly as all the main track-signals are to be fitted with a distant signal and an advance signal.

Roumania.

22. *E. R.* — No apparatus has been tried or adopted so far.

QUESTION 4 (*a, b, c*). — *a) What appliances are used on the locomotive?*

b) Are the strikers fixed to spring-supported parts of the locomotive or not?

c) Must these strikers be adjusted before each trip? What instruments are used for this purpose?

Great Britain and Ireland.

9. *G. E.* — *a*) A plunger piston carried on springs which, being actuated by a treadle, in turn operates mechanically the brake apparatus when the signal is at « danger ». When the signal stands at « line clear », however, it picks up an electric current from the treadle which, by electric means, stops the working of the brake apparatus.

b) Yes; they are carried on the main frame.

c) No; they are automatically checked at each treadle.

10. *G. W.* — *a*) A movable shoe, a bell, a siren and an electric battery.

b) Yes; they are carried on the engine framing.

c) No; they do not require to be adjusted.

11. *L. S. W.* — *a*) Visual and audible signals and a valve on the train-pipe.

b) Yes; they are carried on the engine framing.

c) All parts of the apparatus should be adjusted.

12. *N. E.* — *a*1) *Mechanical* : a striker between slides governed by springs which operates a valve on the air or steam brake. A whistle, blown by air or steam, on the opening of a valve by the action of the striker.

*a*2) *Electrical :* a shoe on slides working as a cut-out. Steel-wire brushes to receive the track current : the shoes and also the brushes are spring-supported. A visual indicator consisting of a number of semaphore arms. An electric bell as audible signal. An electro-magnet controlling the valve for causing the brakes to be applied in the case of the air-brake system.

b) Yes; they are carried on parts that are spring-suspended.

*c*1) *Mechanical :* no; the contact-levers being spring-controlled, allow some variation of the position of the spring-supported frame of the locomotive. They are adjusted with ordinary spanners.

*c*2) *Electrical :* no; the sliding shoe and the steel-wire brushes being spring-supported allow for variation of the position of the spring-supported frame of the locomotive.

13. *N. St.* — *a*) Sliding contact shoes, mechanical application of the brake, apparatus

for insuring return to normal position, a bell and a whistle for audible signalling.

b) They are carried on spring-supported parts.

c) From our experience we should say, no! A control treadle might be used with the object of checking the contact made by the shoe.

Australia.

15. *N. S. W.* — *a, b, c*) Reference should be made to the published descriptions of this apparatus which are doubtless available.

QUESTION 4. (*d, e, f, g*). — *d*) *What means are used for giving the signal on the locomotive? Steam, compressed air or electricity?*

e) Is the audible signal given by a bell or by a whistle?

f) Does the audible or visible signal on the locomotive automatically stop working, or is it stopped by the driver?

g) Can the driver throw the whole apparatus out of action?

United States of America.

6. *S. R. S.* — *d*) Compressed air and electricity.

e) By whistle only during the trials.

f) During the trials the whistle stopped sounding automatically.

g) The driver cannot throw the apparatus out of action.

Great Britain and Ireland.

8. *G. C.* — *d*) There are no visual signals; the method adopted for repeating the signal is the same as that used for the application of the brake.

e) The audible signal is given by a whistle.

f) The audible signal, which is accompanied by gradual application of the brake, continues until it has been stopped by the driver.

g) The driver cannot throw the apparatus out of action.

9. *G. E.* — *d*) Compressed air and electricity for air brakes. Steam and electricity for steam brakes.

e) A whistle for « danger ». A bell for « line-clear ».

f) The signal for « line-clear » given by the bell stops automatically. The whistle must be stopped by the driver.

g) The driver cannot throw the whole apparatus out of action.

10. *G. W.* — *d*) Electricity for the bell. The air passing through the train-pipe causes a siren to sound.

e) The bell for repeating « line-clear ». The siren for repeating « danger ».

f) The « danger » signal is put out of action by the driver. The « line-clear » signal is stopped automatically.

g) Yes; the driver can throw the whole apparatus out of action.

11. *L. S. W.* — *d*) Electricity and detonators.

e) It is given by both.

f) It is stopped by the driver.

g) Yes; but he must take action deliberately.

12. *N. E.* — *d*) Compressed air and steam in the case of a mechanical system; electricity in the case of an electrical system.

e) By a whistle in a mechanical system; by a bell in an electrical system, but, in the latter case, there is also a visual indicator.

f) The working of the whistle is stopped by the driver. The electric bell rings, or stops ringing automatically, according to the position of the visual indicator.

g) In the mechanical system he cannot; in the electrical system he can throw the whole apparatus out of action, with the present arrangement.

13. *N. St.* — *d*) Steam and electricity.

e) It is given by a bell when the signal is at « line-clear » and by a whistle when there is application of the brake.

f) The signal given by the bell stops automatically. The steam whistle ceases to sound when the driver restores the brakes to normal position.

g) No; the driver cannot throw the whole apparatus out of action.

Australia.

15. *N. S. W.* — Reference should be made to the published descriptions of this apparatus, which are doubtless reliable.

QUESTION 4 *(h, i, k, l, m). — h) What devices are placed on the track? Where are the tripping devices placed : between the rails, or on one side of the rails, or above, supported on poles?*

i) Are the tripping devices fixed or movable? Are they affected by the position of the signals?

k) At what intervals are the devices examined or tested?

l) If contact bars or treadles are used what is their length?

m) How many inches do the contacts project into the loading gauge proper? And how many inches into the cross-section of the clear space above the track? By how many inches do the locomotive strikers and tripping devices overlap each other?

United States of America.

6. *S. R. S.* — *h*) There is no apparatus placed on the track.

i) In the system tried there are no tripping devices on the track exposed to shock.

k) While under trial the apparatus was constantly under inspection.

l) No treadles are used.

m) There are no striking levers or contacts.

Great Britain and Ireland.

8. *G. C.* — *h-i*) With the object of obtaining partial application of the brake the track-apparatus consists of a short treadle arranged in a horizontal plane and placed in the six-foot way, the whole apparatus being itself fixed. In order to obtain an absolute stop there is an apparatus arranged with a vertical shaft capable of rotation, the upper end of this carries an arm, acting in the horizontal plane, which, when the corresponding signal is in the « danger » position makes an angle of 90° with the rail and breaks an easily-fractured wooden strip carried on the locomotive : but when the signal is in the « line-clear » position the arm is turned away from the rail in such manner that it does not come into contact with the apparatus carried on the locomotive. The apparatus described above is also fixed in the 6-foot way.

k) The fixed apparatus for the partial application of the brakes is inspected every day by the ganger, whereas the movable apparatus for the complete application of brakes at the stop signal is checked, every time that it works, by means of a special electric circuit which shows the signalman in his cabin that it is working properly.

l) The treadle bars for the partial application of the brakes have a length of about two feet.

m) The contact treadles and the arms do not enter the loading gauge of the locomotives, but they are placed in the clear space between the loading gauge of the locomotive and the track. The total overlap of the strikers and tripping devices is 1 1/2 inches.

9. *G. E.* — *h*) The apparatus placed on the track consists of treadles 40 to 75 feet long according to the speed run on the section. They are placed a short distance before the signal, but they can also be placed in any other convenient position.

i) They are fixed. They are supplied with electric current when the signal stands at « line-clear », but are without current when the signal stands at « danger ».

k) They are not inspected at regular intervals. Inspection is made whenever it is thought to be necessary.

l) The length of these treadles is from 40 to 75 feet according to the speed run on the section.

m) 4 to 5 inches above the level of the rails (they do not enter the loading gauge of the locomotive). They exceed the construction gauge of the track by 1 1/2 inches and in many cases by 2 1/2 inches.

10. *G. W.* — *h*) A treadle between the rails.

i) They are fixed.

k) Whenever the locomotive leaves the shed.

l) The length of the treadles is 40 feet.

m) They are below the loading gauge of the locomotive.

11. *L. S. W.* — *h*) There are several pieces of apparatus : a movable treadle, a fixed treadle, and a conductor emitting electric waves.

i) Experiments have been made with fixed details as well as with movable parts. They are controlled by the position of the signal.

k) Generally before each trip.

l) There are no bars, but only treadles the length of which is about four feet.

m) The contacts are outside the loading gauge of the locomotives. The shoe or contact-lever comes outside the loading gauge by about 1 1/2 inches.

12. *N. E.* — *h, i, k, l)* In the mechanical system the tripping device, subject to shock on the track, is arranged close to the signal, between the rails. It consists of strong projections carried on a rod acting in connexion with the signal in such manner that the projections encounter the striker carried on the locomotive, but only when the signal is at « danger ». The contact between these projections and the movable sliding striker is only instantaneous. In the electric system the apparatus arranged on the locomotives is operated by long bars, arranged between the rails, at suitable places for working the apparatus. The usual length of the bars is 30 feet for distant signals and 60 feet for stop signals. The shoe is raised with the object of interrupting a normally-closed circuit; the shoe and the brushes slide on the bars; the brushes take, from the bars, current produced in the signal cabin.

i) In the mechanical system the tripping devices are movable; they are thrown over into a position in which they do not come into action when the signal stands at « line-clear ». They are raised into the position for making contact when the signal stands at « danger ». In the electrical system the tripping devices are fixed. The current is supplied to the bars by the signal cabin when the signal stands at « line-clear »; it is not sent when the signal stands at « danger ».

k) In the mechanical system they are inspected every day. In the electrical system they are always subject to the observation of the signalman in the cabin from which the signal is operated. Moreover they are inspected and tried every week by the maintenance staff.

m) In the mechanical system contact bars are placed two inches below the loading gauge of the locomotive. The clear space over the rails is 4 inches. The overlap of the parts is 3/4 inch. In the electrical system the bars fixed on the track stand 4 1/2 inches above the track-rails. The shoe, carried by the locomotive, when it is not making contact with the bar, hangs at about 3 inches above the track-rails.

13. *N. St.* — *h*) A treadle with which the shoe carried on the locomotive makes contact. The treadle is arranged in the centre between the track rails.

m) The contact shoe carried by the locomotive projects 1 3/4 inches beyond the loading gauge of the locomotive. It does not project into the structure gauge of the track. The overlap is 1 1/2 inches.

Australia.

15. *N. S. W.* — *h, i, k, l*) Reference should be made to the published descriptions of this apparatus which are doubtless reliable.

m) Projection beyond the structure gauge of the track, 2 1/2 inches. Projection beyond the loading gauge of the locomotive, nil. The parts of the locomotive and those of the track overlap by 1 1/2 inches.

QUESTION 4 *(n, o, p, q, r, s).* — *n) Have experiments been made with a view to utilizing waves (light, electric waves, magnetism, etc.)? What results have been obtained?*

o) If the apparatus does not work, for some reason or other, or if any part of it is damaged, is a warning signal given to the driver? And are the brakes put on simultaneously?

If the brakes are put on, can the driver take them off before the train has come to a standstill?

p) Is the working of the apparatus independent of the weather conditions (snow, ice, etc.), of the speed, of the wear and tear of the vehicles and track, and finally of vibrations and shock?

q) What parts of the apparatus have most frequently been out of order?

What are the causes of these troubles?

r) Are the apparatus equally suitable for steam and electric railways whatever system may be in use?

s) Can the apparatus be used on special portions of the tracks, such as in tunnels and along bridges?

United States of America.

6. *S. R. S.* — *n*) Yes; the Buell signalling apparatus. Trials were made in April 1906, and at various times up to 1910 on a short section of track arranged in North Virginia and for a short period on a longer section in Kentucky.

o) When the system is damaged or deranged the brakes are applied automatically. The driver can take the brakes off whenever he desires, but in taking off the brakes he records this on a recording dial.

p) Yes; it is believed to be proof against any bad weather.

q) The most common derangements of some parts of the apparatus have been caused by the interruption of the current due to trouble with the wires laid on the ground, particularly in case of bad weather. The most frequent causes of these troubles are due to deterioration of the wires and joints caused by the action of the cinders.

r) No; the apparatus tested is only suitable for lines worked by steam.

s) Yes; this apparatus can be used on short sections and the trials themselves were confined to short sections of track.

Great Britain and Ireland.

8. *G. C.* — *n*) We have not made any trials of this kind.

o) Any kind of failure of the apparatus on the locomotive shows itself at once by causing application of the brake, whereas in the case of the track apparatus a failure of any kind is shown electrically in the signal cabin. If the brakes have been applied the driver can take them off in the case of their being partially applied, but he cannot do so, if the brakes have been fully applied, until the train has come to rest.

p) The working of the apparatus is independent of all ordinary weather conditions and one may be certain that it could continue to work under any bad weather through which the signal service itself could work. With regard to speed it works satisfactorily at speeds exceeding 80 miles per hour, and the apparatus is of such construction that there is sufficient adjustment to compensate for the wear of the vehicles as well as of the track in a vertical direction; vibrations and shocks do not disturb the working of the apparatus.

q) We have had no trouble with any parts of the apparatus.

r) The apparatus is equally applicable to lines worked by steam and to those worked by electricity. Moreover it is particularly suitable for the latter, because, in this case, there is no fear of stray earth-currents giving a wrong indication of « line-clear ».

s) The apparatus has been applied in tunnels and on bridges.

9. *G. E.* — *n*) No; these trials have not been made.

o) Yes; in case of failure to act, or of damage to the apparatus, warning is given and the brake is applied at the same time. The driver can take the brake off in the case of distant signals; he cannot do so in the case of stop signals.

p) Yes; it is independent.

q) The electric connexions, owing to the slacking of the nuts.

r) Yes.

s) Yes.

10. *G. W.* — *n*) No; trials of this kind have not been made.

o) Yes; in this case warning is always given and the brake is applied at the same time. Yes, the driver can always take the brakes off.

p) Yes; it is independent of all bad weather conditions.

q) Defective accumulators; defective cutouts. The contact shoe outside the loading gauge; defective battery-wires on the locomotive. The causes of these troubles are the ordinary derangements of the accumulators; dirty and worn contacts; the vertical movement of the locomotive frame on the springs.

r) The contact shoe and the treadle being

placed between the rails prevent the use of a central rail on an electrified track.

11. *L. S. W.* — *n*) Yes; we have made trials with electric waves; the results were satisfactory, but the apparatus was too costly.

o) Yes; in this case a warning is always given and the brake is applied simultaneously; the driver can always take the brake off.

p) Yes; it is independent.

q) We have not had sufficient experience to be able to state definitely.

r) Yes.

s) Yes.

12. *N. E.* — *n*) No.

o) *Mechanical system* : if it is not damaged it gives no warning. If it is damaged it immediately gives warning by the application of the brake. The driver can always take the brake off. The apparatus does not take the brake off automatically. — *Electrical system :* The apparatus is so constructed that the permanence of the repeating signal depends on a closed circuit. If this circuit is interrupted a repeating signal of « danger » is given automatically. When the track signals are in the position of « line-clear » the repeated signals for « danger » are automatically prevented from showing by current from the signal cabin from which the signal is operated. If this current were stopped the signals would go to « danger ». The brakes are applied whenever the locomotive passes over a bar placed near the signal when there is no current flowing through this bar. As the apparatus is at present constructed the driver can take the brake off after the apparatus has caused its application.

p) *Mechanical system* : It is independent of all difficulty from bad weather conditions and speed. — *Wear* : It should be adjusted on account of the wear of the vehicle and the set taken by the locomotive springs. — *Electrical system* : The apparatus is mainly liable to derangement by the formation of ice, which prevents the current from the signal cabin being picked up when the signal is in the « line-clear » position.

q) *Mechanical system* : the contact shoes (strikers) owing to the shocks. — *Electrical system* : The chief cause of failure has been the formation of ice which prevents picking up the current from the signal cabin. Some fractures of the shoes have occurred and of the wires connecting them with the brushes but the latter have been fairly uncommon. There have also been some derangements of the electric indicators caused by breakage of the internal wires; the following table will give an idea of these derangements.

Failures of the locomotive apparatus :

1918	109 %
1919	360 %
1920	840 %

Failures of the track apparatus :

1918	150 %
1919	370 %
1920	124 %

r) Yes; if the centre of the track is not occupied by other apparatus.

s) Yes.

13. *N. St.* — *n*) No.

o) Yes. In this case a warning is always given and the brake is applied simultaneously, the driver can always take the brake off.

p) Yes; it is independent.

s) Yes.

Australia.

15. *N. S. W.* — *n*) No.

o) Yes. In this case warning is always given and the brake is applied at the same time; the driver can always take the brake off.

p) We have had insufficient experience to enable us to make a statement at present.

q) Yes, it is independent.

r) They are only suitable for tracks worked by steam.

s) Yes.

Questions 5, 6 and 7. — 5) *Are all your locomotives already fitted with appliances for repeating the track signals on the locomo-*

tive? If not, is it intended to equip all of them in this way?

What types of locomotives are at present equipped in this way, and for what service are they used (passenger or goods)?

What length of track is equipped in this way, and how many tripping devices are there altogether?

6) *Do you consider it necessary that the apparatus on the locomotive should only warn the driver he is approaching a signal without indicating if it is at « clear » or at « danger », or whether it is preferable to show line clear or blocked?*

7) *Do you consider it sufficient if the apparatus on the locomotive only indicates to the driver the position of the signal, that is, simply repeats the signal? Or must it in addition thereto, also record the position of the signal?*

Is your apparatus so arranged, that it only records the « danger » position of the signal, or does it record both the « danger » and the « clear » position?

Belgium.

1. *E. B.* — 5) There are none.

6) The apparatus should work on the locomotive when the signal is at « danger » and when it is at « line clear », as laid down in the programme under sub-question 2.

7) The apparatus should give an audible warning of the position of the signal and act on the brake when a danger signal standing at « danger » is run past.

United States of America.

6. *S. R. S.* — 5) No, none of our locomotives have been so fitted up to the present. No part of the track is fitted with treadles and we have no contact-gear.

6) We consider it desirable that the apparatus on the locomotive should show « line-clear » as well as « danger », whereas there would be too much risk of complicating matters if an attempt were made to repeat « line-clear », « caution » and « danger ».

7) The apparatus that has been tried is so arranged as to repeat « line-clear », or « danger ».

Great Britain and Ireland.

8. *G. C.* — 5) At present the greater number of the locomotives running on the London-suburban service are so fitted. These locomotives are 4-6-2 tank-locomotives hauling passenger trains. The length of track equipped is 11 miles and the number of track-contacts installed is : for partial application 26, for stop 51.

6-7) At present we use the Reliostop system by which an audible warning is given on the locomotive on approaching a distant signal. It is therefore only a question of a warning of position, whether the signal stands at « danger » or at « line-clear ».

9. *G. E.* — 5) Our locomotives are not all fitted with repeating apparatus. The types of locomotives that are so fitted are passenger tank-locomotives and goods locomotives with tenders. Nine signals have been installed on a section of track 20 miles in length and three on another section.

6) It is preferable to show him whether the signal is at « line-clear » or is at « danger ».

7) We think that it should only repeat the position of the signal. Our apparatus is arranged in such manner as to record a signal at « danger » as well as the signal at « line-clear ».

10. *G. W.* — 5) No; only ninety-nine locomotives are fitted with it, of all types, both passenger and goods. The length of track fitted is one hundred and eighty-eight miles with a total number of one hundred and ninety-two contact-treadles.

6) It should show whether the track is « clear » or whether it is « blocked ».

7) It is sufficient when the apparatus is applied to distant signals. It then follows that the position of the signal is repeated. The signals for « line-clear » as well as those for « danger » are repeated, but they are not recorded.

11. *L. S. W.* — 5) The systems described above have been tried, but only experimentally, on this Railway System. The length of track equipped has varied according to the system tried. The Prentice wireless-signalling system was installed on about four miles of track.

6) The driver should receive an indication of whether the track is « clear » or whether it is « blocked » in agreement with the conditions on the section beyond.

7) It would be necessary to have a record of the signal repeated in the locomotive cab. The wireless signalling system recorded both of these.

12. *N. E.* — 5) No; only the locomotives that work on stretches of track equipped for experiments are so fitted. No other equipment has, as yet, been put to work. The locomotives equipped are passenger or goods locomotives and many of the former run on express services. The length of track equipped is in the case of the mechanical system, eighty miles, and, in the case of the electric system, forty-five miles of single track.

6) It is thought necessary to warn the driver of the train when approaching a distant signal, at some distance before he reaches it, and to repeat to him, at each distant signal, whether : *A.* All the stop signals controlling access to the section beyond are at « line-clear ». — *B.* All or some of the stop signals are at « danger » and to confirm the latter condition at each stop signal when it is approached.

7) It has not been thought necessary to record any of the signals repeated.

13. *N. St.* — 5) No; our locomotives are not fitted with repeating apparatus and we have not yet considered the possibility of so fitting them. None of our locomotives has been so fitted and no section of our track is equipped.

6) It should give warning equally for « danger » and for « line-clear ».

Australia.

15. *N. S. W.* — 5) Only a dozen locomotives are fitted at present, but quite recently it has been decided to fit all the locomotives with apparatus. The locomotives in question are ordinary passenger and goods locomotives. The track equipped is about one hundred miles in length and twenty-seven contacts have been installed.

6) Both « line-clear » and « danger » should be repeated.

7) The apparatus should record the position of the signal. The apparatus used at present records both the « danger » position and that of « line-clear ».

Holland.

21. *E. P. B.* — 5) Apparatus for repeating the track signals is no longer in use.

6) It does not appear to us to be useful to warn the driver.

22. *E. R.* — 6) We think it preferable.

To differentiate between « danger » and « line-clear ».

7) It is preferable that the apparatus should be at the same time warning and recording. By this method the final responsibility of the driver will be better determined.

QUESTIONS 8, 9, 10. — 8) *Do you consider it better for the tripping device which operates the cab signal when the locomotive passes, to be placed at the same point as the track signal itself, or, on the contrary, to be placed a sufficient distance in advance of it, so that the driver, having been warned, can still see the track signal before he passes it?*
In the latter case, at what distance in advance of the track signal is the tripping device placed?

9) *Do you consider it necessary to make it possible for the driver, at the moment he is approaching a signal, if he has seen that signal in time, to stop the operation of the cab signal, but not the recording of the position of the signal, the act of the driver being recorded so that it is possible to check whether he acted before or after the recording of the position of the signal, and so ascertain whether the driver was vigilant, or whether, on the contrary, he allowed himself to be taken unawares by the signal?*

10) *Can the cab signal adopted by you be used equally well on single-track and on double-track sections?*

If not, what modifications have or will be made in order to make its use possible, including electric railways?

Belgium.

1. *E. B.* — 8) The track apparatus should be placed 200 m. (220 yards) before the warning signals.

9) Yes.

10) No apparatus has been adopted.

United States of America.

6. *S. R. S.* — 8) We have no experience in treadle-control because the apparatus with which we have made experiments is of the continuous type.

9) The Buell apparatus with which we have made experiments has a paper recorder for showing the « taking off » of the brakes by the driver after their automatic application.

10) Yes; the cab-signal with which we have made experiments can be used equally well on single lines and on double tracks.

Great Britain and Ireland.

8. *G. C.* — 8) The apparatus that causes partial application of the brakes is placed about 200 yards before the distant signal, whenever this is an independent signal, whereas when it takes the form of the lower arm on a stop signal the apparatus is arranged at the foot of the signal. All the appliances for the complete application of the brake are placed before the signal that they protect.

9) We are not equipped with recording appliances as these are not thought to be necessary.

10) The Reliostop apparatus is equally applicable to single lines and to double tracks; it is also equally applicable to lines worked by steam and to those worked by electric traction.

9. *G. E.* — 8) We consider that in the case of distant signals it should be placed before the signal. On the other hand in the case of stop signals it should be placed immediately beyond. In the case in which the apparatus is placed some distance from the signal this distance will depend on circumstances.

9) No; we do not consider it necessary.

10) Yes; by using current which is respectively positive or negative.

10. *G. W.* — 8) It is placed 400 yards before the track-signal. At a distance of 400 yards before the driver passes the signal.

9) The cab-signals are not recorded.

10) Yes; it can be used equally well in both cases and also for electric traction.

11. *L. S. W.* — 8) The contact-apparatus should be near the signal.

9) The apparatus should work equally well in all cases, that is to say that it should always work automatically.

10) The Prentice wireless system, detonators in case of fog, and a system of signal lights also in case of fog. These can be used equally well for single lines and for double tracks.

12. *N. E.* — 8) *Mechanical system* : the track contact-apparatus has been placed alongside the track-signal. — *Electrical system* : as we have already stated an indication is given on approaching a distant signal, usually at about 150 yards before the signal itself.

9) *Mechanical system* : As we have already stated, the driver can stop the working of the cab-signal on the locomotive and no record has been thought necessary. — *Electrical system* : the apparatus is so arranged that it is not necessary for the driver to stop the working of the cab-signal. The « danger » signal continues untill all the signals in the « danger » division have been dropped and superseded.

10) Neither of the two types of apparatus has been used on single lines. With an electric traction system some small modification of the apparatus would be necessary to enable it to be used on single lines.

13. *N. St.* — 8) It should be placed a little before the signal. The N. S. R. treadle has

been placed 65 ft. 6 in. before, measured to the centre of the treadle.

10) Yes; by making it suitable with an electric equipment.

Australia.

15. *N. S. W.* — 8) The track apparatus should be placed some distance before the signal, and the distance adopted is 300 feet.

9) The driver cannot throw the apparatus out of action.

10) The apparatus can be used equally well for single line and for double-track sections.

Roumania.

22. *E. R.* — 8) We think that the apparatus in question should be placed at a distance of 500 m. to 800 m. (550 to 880 yards) before the signals (500 m. or 800 m. according to the gradients of the line, in order to allow for the application of the brake to the train in time to avoid passing the signal).

9) We consider, notwithstanding the utility of the arrangement described in this question, that it is better not to complicate the apparatus.

10) We have not adopted any up to the present.

Questions 11, 12, 13, 14. — 11) *When the cab signal system was adopted, were the distant signals done away with, or do you at least think that you can do away with them without inconvenience?*

12) *What is the approximate cost of this apparatus :*

a) Per locomotive;

b) Per signal?

What parts cost most for maintenance?

13) *As regards the repetition and recording, on the locomotive, of the positions of the track signal, is this made compulsory by any regulations or is this left to your own initiative?*

14) *Do you consider it an advantage for the warning apparatus to act on the brakes in combination with apparatus for stopping automatically?*

Have you tried this system, and with what arrangements (please give a description with explanatory drawings and photographs explaining it) and state the results obtained?

In case of the automatic stopping system, have you discarded the distinct audible signal when the line signal shews « clear »?

Belgium.

1. *E. B.* — 11) No; on very important lines it is even necessary to arrange electric repeating lamps and to light them when the atmospheric conditions prevent good visibility of the signals at night.

13) Not at present.

14) Yes; as we have already said, the programme of working of the apparatus should be as follows : *a*) when the distant signal stands at « danger », to give, 200 m. (220 yards) before this signal, a whistle blast which cannot be stopped except by the driver taking action.

b) When the distant signal is at « line-clear » to give a different whistle blast.

c) To apply the brakes automatically and gradually at the distant signal if the driver does not take action to silence the whistle requiring him to stop.

d) To apply the brakes automatically when the home signal standing at danger is run past.

United States of America.

6. *S. R. S.* — 11) When these experiments were made the distant signals were not taken into consideration and we do not think this desirable even though cab-signalling should be fitted on all the locomotives.

12) We have not sufficient data to enable us to estimate this expenditure, although the cost of the apparatus, with which we have made experiments, was approximately $350.00 per locomotive exclusive of the cost of the track-signals.

13) During the experiments which we have made, the cab-signals showed the position of the track-signals and we consider that this is

desirable and that it may be of use to the driver.

14) Yes; we consider it desirable that there should be a warning apparatus in combination with the brake valve. For the description of this arrangement see the particulars. This description is taken entirely from the data given by the inventor and it shows all the results obtained when we made the trials, but the apparatus was not then sufficiently near perfection for it to be considered quite satisfactory.

Great Britain and Ireland.

8. *G. C.* — 11) As the apparatus does not act differently for the distant signal when at « line-clear » and when at « danger » the question of suppressing these signals does not arise.

12) As the prices are continually subject to variation we cannot give definite figures, but the system in question is, doubtless, among the cheapest, if it is not the cheapest that has been introduced up to the present into existing practice. During the five years of experiment in actual service the renewals that have been necessary have been practically negligible.

13) There are no regulations in this country regarding cab-signalling.

14) Our apparatus acts on the brakes only, by doing all that is necessary when continuous brakes are used. We have used no automatic apparatus, for long past, for shutting off steam, but there would be no difficulty in extending the range of the gear in this direction if it were thought desirable.

9. *G. E.* — 11) It has been preferred to retain them.

12) It has not been in use for long enough to enable us to state.

13) There are no regulations.

14) We consider it of advantage.

We have made applications of the system.

The audible signal has been retained.

10. *G. W.* — 11) The distant signals have been abolished on some sections of single line.

12) £108 per locomotive and £102 per signal. The parts that require the greatest expenditure on maintenance are the contact pieces of the shoe.

13) There are no regulations.

14) Yes; we think it of advantage. The audible signals have been retained.

11. *L. S. W.* — 11) No system has been adopted up to the present.

12) We cannot state exactly.

13) Up to the present nothing has been done in this direction.

14) No; we do not consider it of advantage.

No; we have not made experiments with this system.

We have adopted no system up to the present.

12. *N. E.* — 11) No; they have not been abolished, nor has their removal been considered.

12) *Mechanical system :* approximate cost £4-9-1 per locomotive; £7-8-9 per signal. The parts that require greatest expenditure on maintenance are the contact pieces. — *Electrical system :* When this was used for the first time its cost was approximately £25 per locomotive and £10-4-0 per signal. The parts on the locomotive require the greatest expenditure on maintenance.

13) This is not done according to any regulation.

14) We have already replied to the matters mentioned in this question.

Australia.

15. *N. S. W.* — 11) The track distant signals have not been abolished nor is it thought desirable to do away with them.

12) We are not in a position to be able to state this exactly at the present time.

13) This is left to the initiative of the Railway Commissioners.

14) It should act on the brakes only to a limited extent. No other system has been tried.

Holland.

21. *E. P. B.* — 13) The repetition of track-

signals on the locomotive is left to our own initiative.

14) We consider it would be advantageous for the apparatus to be able to act on the brakes.

Roumania.

22. *E. R.* — 11) We have not adopted repeating apparatus up to the present.

13) No; there are none that we have to observe.

14) We think it more advisable that the warning apparatus should not act automatically on the brakes, as one cannot be certain that a train following might not come into collision with one stopped in advance of it (when two trains are following closely behind one another).

APPENDIX B.

Apparatus for recording the running-speed on locomotives.

QUESTION 1. — *Are all locomotives on your road equipped, or are they going to be equipped, with speed gauges?*
What types of locomotives are so equipped, and for what service are they used (passenger or goods)?
How many speed gauges of the different systems are in use on your road?

Belgium.

1. *E. B.* — 1) The application of speed-indicators is not required on all locomotives of the Belgian State Railway; only a small number are fitted with them. The appliances are fitted to locomotives of different types, they will be fitted to 75 locomotives of the type *8bis* (*8a*) now under construction (locomotives with six coupled-wheels 1.80 m. (5 ft. 10 7/8 in.), in diameter with a leading bogie intended for hauling passenger trains on the Brussels-Arlon line (gradients 16 per mil); we have in service a small number of the Deuta-Werke type on locomotives handed over by the Germans.

Denmark.

2. *E. D.* — 1) All the locomotives used for hauling trains are fitted with speed-indicators. We use these indicators only to show the approximate speed with a view to assisting the driver, and we do not consider it necessary to use them as real recording instruments.

Spain.

3. *A.* — 1) We have ten goods locomotives of the Du Bousquet type fitted with the Flaman speed-indicating and recording apparatus. We shall shortly put into service 15 mixed locomotives fitted with the same apparatus.

4. *N. E.* — 1) The (291) modern locomotives of our Company, for passenger and goods trains, have all been fitted with speed-indicating and recording apparatus on the Hasler system. The apparatus is somewhat delicate; moreover the drivers do not take great care of it, as they consider it an adverse witness to them in case of exceeding the maximum speed allowed; it follows that, notwithstanding the high cost of maintenance, the number of apparatus normally at work is extremely small.

United States of America.

5. *E.* — 1) No; the locomotives are not all fitted. Only about 35 passenger locomotives of the Pacific type are fitted with speed-indicators. We have only the Boyer type of speed-indicator in use.

6. *S. R. S.* — 1) None of the locomotives used on our service are fitted with a speed-indicator or recorder; speed-recorders have

been used fairly largely on passenger locomotives some time ago, but not continuously.

7. *B. & O.* — 1) No; all the locomotives are or ought to be fitted with the apparatus; on our Railway System only the following classes of locomotive are fitted with speed-indicators.

Type of locomotive.	Number of locomotives.	Type of locomotive.	Number of locomotives.
Passenger locomotives.			
A-1	6	I-1	1
A-2	19	I-6 to B	7
A-3 to 74	26	I-6-68	4
B-7	2	I-6-72	9
B-7 to B	1	M-1	5
B-8 to B	7	M-2	6
B 14	11	M-162	4
B 15	4	M-odd. to B	2
B-17 A	9	M-60-68	12
B-18 A-188	15	M-68	3
B-19 A	12	P-Pa	35
B-24	1	P-la	
B-45 A	3	P-laa	36
C 10	3	P-lb	
G-17	1	P-3	30
H-8	2	P-4	10
H-8-106	6	P-5	10
H-9	1		
Goods locomotives.			
B-8	13	E-10	1
B-29	4	E-8-60	4
B-2	1	B-25	1
Total passenger locomotives.			303
Total goods locomotives			24
Total number of locomotives.			327

The passenger locomotives as well as the goods locomotives are fitted on this Railway System with speed-indicators. The Boyer speed-indicator is used.

Great Britain and Ireland.

14. *M. G. W.* — 1) We use speed-indicating and recording apparatus carried in a special van which can be attached to any train. We only use this type.

Australia.

15. *N. S. W.* — 1) No; at present they are not all fitted with a speed-indicator. Both goods and passenger locomotives. This department has made experiments with speed-indicators on the Boyer, Flaman, Hasler, and Le Quertier systems and has decided in favour of the Flaman.

Indian Empire.

16. *N. W.* — 1) No; only a few locomotives were fitted with speed-indicating and recording apparatus with the object of making experiments, and the appliances were not even installed in a permanent manner on the locomotive as they were removed after the experiment.

17. *B. B. C.* — 1) Only 14 speed-indicating and recording appliances of the Hasler type have been fitted on locomotives of the following classes : 4 of class « O », 4-4-0, with outside cylinders; 4 of class « M », 4-4-0, with inside cylinders; 5 of class « P », 4-6-0, with outside cylinders. All these are passenger locomotives. We only use this type.

Greece.

18. *E. G.* — 1) Some of our locomotives are fitted with the Swiss Hasler apparatus.

19. *P. A. P.* — 1) Fifty-five locomotives out of a total of eighty-two are fitted. All the locomotives running on passenger service. Various classes : 2-8-0; 2-6-0; 2-4-0. Only one system of speed-indicator is used.

Norway.

20. *E. N.* — 1) All locomotives on fast trains and passenger trains are fitted with a speed-indicator. The locomotives on goods trains and shunting locomotives are not fitted. In a division comprising 475 locomotives actually about 200 are fitted with speed-indicators.

Holland.

21. *E. P. B.* — 1) The locomotives on our system are not all fitted with speed-indicators. There are actually 253 express locomotives in service, 62 goods locomotives, and 4 suburban locomotives fitted with the Stroudley speed-indicator; 30 express locomotives fitted with the Haushaelter speed-indicator; 116 locomotives fitted with the Hasler speed-indicator

and 32 express locomotives fitted with the Deuta-Werke speed-indicator.

Roumania.

22. *E. R.* — 1) A small number of our locomotives for express and fast trains are fitted with Hausshaelter speed-indicators. This apparatus indicates and records speed and position as well as the time of running and of stoppages. It renders appreciable services in case of enquiries.

Sweden.

23. *E. S.* — 1) All the locomotives on the State Railways should be fitted with speed-indicators with the exception of the shunting locomotives and of those of old classes. Six hundred locomotives are fitted with speed indicators of five different systems : Penta, Hausshaelter, Hasler, Brinkmann and Kalb. The number of the Penta speed-indicators is about 500; of the Hausshaelter 65. The other systems are represented by a few appliances purchased with a view to trials.

24. *B.* — 1) *a*) Only those locomotives having a speed exceeding 60 km. (37.3 miles) per hour have to be fitted with a speed-indicator according to the regulations. — *b*) Thirty-three locomotives for stopping and fast trains. — *c*) Two different systems.

25. *H. N.* — 1) *a*) No; only locomotives which have to haul trains at a speed exceeding 60 km. per hour are fitted with speed-indicators (Swedish law No. 40. 1905, § 21). — *b*) 5 locomotives, of the 1 C. O. class, which have up to the present been used on passenger-train service. — *c*) Three systems.

Switzerland.

26. *F.* — 1) The Government Regulations require the fitting of recording speed-indicators on all locomotives used for hauling trains. Among the locomotives of the C. F. F. 91 are fitted with Hausshaelter speed-indicators and recorders; 583 are fitted with Hasler (modified Hausshaelter) recorders; 336 are fitted with Klose recorders.

The electric locomotives will in the future be fitted with speed-indicating and recording apparatus on the Teloc system constructed by the Hasler Co. at Berne.

Yugo-Slavia.

27. *S. C. S.* — 1) All our locomotives are not fitted with speed-indicators or speed-recorders, and at present we have no intention of fitting all of those which are not already provided with this apparatus, because the distribution of the locomotives in our country is not completed. The newest of our locomotives are generally fitted with such apparatus as 1) C. E. S. Nos. 109, 110, 21-24, 115-118, 121-126, 151-158, 601-620. Of these locomotives there are at present only a few running; the others have not yet been fitted, or are not in running order, and await repair.

2) M. A. V. of the series : 220, 221, 222, 223, 238, 324, 325, 327, 342, 370, 375, 376, 377, 401, 421, 601 and 651. K. K. St. B. of the series : 2, 4, 106, 29, 229, 329, 429, 32, 34, 37, 47, 48, 55, 155, 56, 59, 60, 260, 65, 170, 270, 73, 178, 80, 180, 380, 86, 88, 394, 97, 99, 199. Of these locomotives about 450 are now running and these are the ones we use for passenger and goods traffic.

Question 2. — *Do you consider it better that the apparatus should only indicate the speed to the driver, that is to say, be a speed gauge pure and simple, or should it also record the speed, that is to say, be a real recording instrument?*

What are the special reasons for having the speed of the train recorded?

Are the advantages of doing this sufficient to counterbalance the cost of the examination of the records, of the paper tape and of the maintenance of the apparatus?

Will this make it unnecessary for the train conductors and the station officials to keep records of the arrival and departure of trains?

Have you done away with the speed contacts on your line, which record the speed of moving trains at stations? If not, why not?

Belgium.

1. *E. B.* — 2) Yes; these appliances should only show the speed; recording appliances are

only used under exceptional conditions with the object of research and experiment. The advantages of recording are not sufficient to compensate for the expense. The Dromopetard is still used. The Boulengé, too well-known to need description. The Dromoscope, which does not fulfil the object in view, has been given up. The Dromopetard has in particular a moral effect on the driver.

Denmark.

2. *E. D.* — 2) We should add that at the present time we are making experiments with the speed-indicator and recorder called the « Minimax », but, up to the present time, we have not obtained final results concerning the working of this appliance. Five fast locomotives, which will be delivered by Borsing (Berlin (will be fitted respectively with the speed-indicating and recording apparatus of the Deuta system and of the Brühn system supplied by the firm of Westendorp and Piper.

Spain.

3. *A.* — 2) We consider that it is of advantage to record the speed of the trains in order to check them and avoid exceeding the permissible limits. The difficulties found in service during and after the war have not allowed us to use these appliances in a normal manner; we cannot speak as to the advantages of recording. We have never had speed indicators arranged on the track.

4. *N. E.* — 2) In order that the speed-indicator may fulfil its functions properly it should not only be an indicator of the running speed, but also should give an exact record of this speed. It is desirable that the continuous speed should be recorded, in order to give information of the running of the train, and to allow of checking the figures returned by the guard on his way-bill. The working of our recording apparatus is much too irregular for us to be able to think of abolishing the particulars kept by the guards and stationmasters relating to the hours of arrival and departure of the trains. We have no speed-indicator on the track to enable the speed to be known in the stations.

United States of America.

5. *E.* — 2) We consider that the apparatus should be indicating and recording in order at the same time to show and record the speeds. We desire this with the object of better regulating the permissible speeds. Yes; the advantages are sufficient to compensate for the expense. No; this does not do away with the information recorded by the guards and stationmasters. We do not use speed-indicators placed on the track.

6. *S. E. S.* — 2) We consider that it is better, when speed-indications are required, as a condition for safety, that the apparatus should be recording and that it can be used or thrown out of gear according to circumstances. A special reason for requiring the recording of speeds is to enable a check to be kept on excessive speed and to obtain a better check of the manner in which the driver observes the regulations for safety of working. The speed-indicating and recording appliances are not necessary, except where there are abnormal conditions and where it is necessary to make corrections for shunting operations, or to rectify the tables of maximum speeds, or when other information is required which might make the paper record desirable. A recording apparatus would not do away with the information recorded by the guard or by other employees relating to the times of arrival and departure of the trains. We have never used speed-indicators, placed on the track, with the object of ascertaining the speed of trains running through the stations.

7. *B. & O.* — 2) The apparatus should record the speed, that is to say that it should be a true speed-recording instrument; actually on this Railway System the indicator records the speed in miles per hour on a paper ribbon, so that it is permanently available. We wish to have this record to enable us to check the speed at which the trains have run between certain points where speed limits are in force, and, in case of accident, in order to have indisputable proof that the train was running at excessive speed. We consider that the advantages that may thus be obtained justify the expenditure. The use of speed-

indicators and recorders has not done away with the information recorded of the time of arrival and departure of the train in the block-signal cabins and in the telegraph offices. The Baltimore & Ohio Co. has no apparatus in the stations for the object of recording the speed of passing trains.

Great Britain and Ireland.

14. *M. G. W.* — 2) Permanent records are desirable. We desire these records with a view to controlling whether the speed limits on some sections of the track are observed, and also with the object of checking the maximum speeds no gradients, etc. Yes; the advantages are sufficient to compensate for the expense of the special diagrams described above. No; this does not enable us to dispense with the information recorded by the guards and stationmasters. We do not use these appliances.

Australia.

15. *N. S. W.* — 2) We think that the apparatus should be a true recording instrument. We wish to have the record in order to check the guards, the drivers, etc. Yes; the advantages compensate for the expense. No; they cannot be abolished. This Department has no speed-indicators arranged on the track.

Indian Empire.

16. *N. W.* — 2) In daily use the apparatus should show the speed with the object of assisting the driver, and, at the same time, it should record it in order to enable the daily work of the driver to be checked. We require this record in order that the driver may be prevented from exceeding the limits of speed on bridges, and in descending steep gradients, and to enable the Administration to check this. We do not know whether the advantages compensate for the expense.

17. *B. B. C.* — 2) That depends entirely on the use which it is desired to make of the apparatus. We require recording only in cases where a special coal is used, or with the object of making other experiments. No; the advantages are not sufficient to compensate for the expense. No; the notes taken by the guard and stationmasters cannot be abolished. We have never used these appliances.

Greece.

18. *E. G.* — 2) We consider that the apparatus should be speed-recording in order that the running of the driver may be checked. Yes; the advantages compensate for the expense. No; they cannot be abolished.

19. *P. A. P.* — 2) We consider that the apparatus should indicate and record speeds and stoppages. We require to have a record with the object of checking the running of the trains. Yes; the advantages compensate for the expense. Yes; they can be abolished. No; there have never been any.

Holland.

21. *E. P. B.* — 2) We think the advantages of speed-recording sufficient to compensate the expense involved in the verification of the diagrams, etc. We have not given up the use of the speed-indicators arranged on the track for enabling us to check the speed of the trains over dangerous places.

Roumania.

22. *E. R.* — 2) We desire to record, as it may be of distinct value in the case of accidents. We think that it is advisable to fit the apparatus only to fast and express train locomotives. No; they cannot be abolished because the accuracy of the recording apparatus is not sufficiently close. We have never had any although their advantage appears self-evident.

Sweden.

24. *B.* — 2) *a*) We think that the apparatus should only indicate the speed of running to the driver. — *b*) In 1900 we fitted three locomotives with speed-indicating and recording apparatus with a view to ascertaining the true cause of delays and particularly the length of the stops. The data obtained produced improvements in the running of the trains, but we thought that continuous control was too expensive. — *c*) Yes; if the driver runs too fast, the traffic superintendent is informed and the driver is ultimately

punished. The speed is generally, and in our circumstances sufficiently well, checked by the time of running. — *d*) We have given up using them.

25. *H. N.* — 2) *a*) As the chief object of speed-indicators is doubtless to show at each moment the speed at which the train is running, we are of the opinion that a speed-indicator should be limited to showing the speed and should not record it. — *b*) We consider recording desirable in the case where a special check is required on the speed of the train, on the stops, etc., and with the object of affording evidence, in case of accident, of an indisputable character regarding the speed at which the train was being driven at the time of the accident. — *c*) We do not consider that the arguments on this question given above show such advantages that they can compensate for the cost of paper and maintenance of the apparatus. The speed-indicating and recording appliances that we have used (Hausshælter) soon wore out. They were replaced by non-recording indicators which have shown themselves more durable and less costly. — *d*) No; they cannot be abolished. — *e*) We have never had any.

Switzerland.

26. *F.* — 2) The C. F. F. give preference to recording appliances because these enable the effective speed of running to be checked, for example, on gradients or on sections where low speeds are necessary, and because they give information relating to the time lost in running or during stops at the stations. The advantages are sufficient to compensate for the expense of checking and maintenance, as these expenses are small. The notes cannot be abolished. The reading of the record diagrams is too difficult for general use. Moreover, it would be necessary that the Hausshælter, Hasler and Klose appliances should be combined with clockwork as in the Teloc apparatus. The C. F. F. only use indicators on the track under certain very special circumstances, on very long underground sections (St. Gothard and the Simplon tunnels). They are, moreover, arranged rather with the view to informing the stations of the position of the trains at any instant, than of checking their speed.

Yugo-Slavia.

27. *S. C. S.* — 2) We think that the apparatus should not only show the driver the running speed, but should also record this speed, both for enabling the driver's work and the running of the train to be checked. We think the utility of the appliance is sufficiently great to compensate for the cost of its maintenance.

With regard to the double check and in view of the fact that such apparatus is intended for the direct information of the traffic service we think that taking note of the times of the arrival and departure of the trains by the traffic staff is necessary.

We have no apparatus for recording the speed at which trains run through the stations, and at the present time we have no intention of introducing them, as we have more urgent expenditure in view.

QUESTION 3. — *What speed-recording devices have you adopted, which of them have you tried, and which are you still trying?*

Please give a detailed description of them, with drawings, also showing how they are actuated; also state what results have been obtained in the tests made with the different types of apparatus.

Does the device record at once any variation in the speed, or does it record average speed only?

After how many seconds does it record the average speed?

Belgium.

1. *E. B.* — 3) Before the war the Belgian State Railway made use of the Flaman apparatus made by the Vaucanson Works, 11, rue de Swanchu, Paris, and of recording apparatus of the Hasler type. These appliances have not been replaced since the armistice. The other systems tried before 1914 have been abandoned. The apparatus that will be fitted on the locomotives of class 8*bis* (8*a*) mentioned above, is the non-recording speeed-indicator of the Tel system made by the Hasler

Co. of Berne. It is described in the *Bulletin of the Railway Congress* (February 1914). The Tel speed-indicator shows the speed every second. This speed is the mean for the last two seconds.

Spain.

3. *A.* — 3) Flaman apparatus as used in France and described in the *Revue générale des chemins de fer.*

4. *N. E.* — 3) The only apparatus tried and adopted by our Company is that made by the Hasler Co. of Berne. The pointer of the apparatus shows the speed of the locomotive every six seconds; it is recorded on the diagram every twelve seconds.

United States of America.

5. *E.* — 3) We have adopted the Boyer speed-indicator and recorder, but we are experimenting at the present time with other apparatus. The apparatus shows the actual speed and this is recorded instantaneously.

6. *S. R. S.* — 3) We have made trials with the Boyer speed-indicator and recorder, which is still in use on some carriages; but it has not been retained on the locomotives. The speed-indicator used on the locomotives showed the speed while the locomotive was running without recording it; the speed was shown by a hand on a four-inch dial. The Boyer speed-indicator and recorder shows the speed on a dial, which can be placed where desired, and it records the speed on a paper strip independently or otherwise of the speed dial. The record-strip is marked while the vehicle is running and all variations of speed are consequently recorded. This apparatus has been used to a great extent in conjunction with the apparatus supplied by Julian Beggs for reducing the speed by means of the air-brakes, the recording-apparatus being so arranged as to cause the application of the brakes when a certain speed has been exceeded.

7. *B. & O.* — 3) The Boyer speed-indicator is our regular speed-indicating apparatus for locomotives, and is fitted to 327 locomotives, as already stated. Other types of speed-indicators have been examined, but none of them has yet been fitted to our locomotives for trial, and we are not in a position, at present, to discuss their advantages. When properly used and kept in good order the Boyer speed-indicator gives good results. The Boyer speed-indicator records the instantaneous speed on a graphical diagram.

Great Britain and Ireland.

14. *M. G. W.* — 3) The special van for speed-recording and speed-indicating can be attached to any train when desired and it is fitted with a Boyer speed-indicator. The apparatus records all variations in speed instantaneously.

Indian Empire.

16. *N. W.* — 3) We have adopted no speed-indicating and recording apparatus for general use; but we have made experiments with many appliances constructed by various inventors such as the speed-indicators of Boyer, Stone's, Jones and Hausshælter. We found the Hausshælter type the most satisfactory, although it is a complicated and delicate piece of apparatus. We have twelve of these on our Railway System, but they are only used when it is desired to make special speed-tests or for tests on bridges, etc. The Hausshælter speed-indicating and recording apparatus shows the speeds in miles per hour about eight times in 1 1/2 minutes, on a moving paper-strip which is perforated by the recording needles. The speeds in miles per hour are thus recorded on a uniform time base and a variable distance base. The recording needle perforates the paper every twelve seconds and the time base is marked with a dot every 1 1/2 minutes.

17. *B. B. C.* — 3) We have only adopted the Hasler speed-indicating apparatus. No; it is not limited to recording the mean speed, but it also records all variations in this speed.

Greece.

18. *E. G.* — 3) We have adopted the Hasler speed-indicator (of Swiss make). The apparatus gives the running and the speed of the locomotive at any instant as a continuous

curve, and it shows the mean speed every five seconds, etc.

19. *P. A. P.* — 3) We have adopted the Sirius apparatus of Dr. W. Schaufelberger of Zurich. This apparatus shows the variation of speed continuously.

Norway.

20. *E. N.* — 3) The speed-indicators used are the non-recording appliances supplied by the « Deutsche-Tachometerwerke ». About twenty years ago a certain number of locomotives were fitted on trial with Hausshaelter speed-indicating and recording apparatus, but these appliances required so much upkeep that it was necessary to take them out after a rather short period.

Holland.

21. *E. P. B.* — 3) The speed-indicating appliances that we have adopted are the following : Hasler, Hausshaelter, Stroudley and Deuta.

Roumania.

22. *E. R.* — 3) We have adopted speed-indicators of the Hausshælter system, which do not give an instantaneous indication of the speed; the record only gives the actual speed when this remains constant for about ten seconds. (Further trials of this are under consideration).

Sweden.

23. *E. S.* — 3) We have adopted speed-indicators of the Penta system and of the Hausshaelter system, and we have also made trials of the Hasler, Brinkmann and Kalb system. There is nothing novel in the driving gear.

24. *B.* — 3*a*) We have adopted the following speed-indicators : Hasler Co. of Berne, Tel system (indicating only). The Horn speed-indicator, Manchester. The Hausshælter speed-recorder.

b) We have made experiments with the Siemens and Halske indicators the Ferrari and Frehm system. (We have tried the Kalb speed-indicator of Hartmann and Braun of Frankfort-on-Main.

c) We have no speed indicators undergoing trial.

d) We have found that the Horn speed-indicator is the most durable.

e) The Hasler speed-indicator of the Tel system shows the mean speed every two seconds.

25. *H. N.* — 3) We use the following speed-indicators : *a*) The Tel speed-indicator made by the Hasler Company of Berne. — *b*) The Penta speed-indicator supplied by the firm of Fritz-Egnell of Stockholm. — *c*) The speed-indicator consisting of a magnetic-indicator and a tachometer with a pointer, manufactured by the Hartmann and Braun Co. of Frankfort-on-Main.

a) The speed-indicator made by the Hasler Co. of Berne is the one, out of all those tried, that has been the longest in use (since 1912) and the one which has proved itself very durable and reliable. The speed is recorded every three seconds. — *b*) The Penta speed-indicator is applied to two locomotives, it has been running for two years and works quite well. All variation in speed is shown instantaneously. — *c*) The speed-indicators supplied by the firm of Hartmann and Braun of Frankfort have recently been fitted to two locomotives. We are not yet in a position to give an opinion regarding them. However this may be, speed-indicators of this type have been fitted to the automotor-cars, fitted with Diesel engines, belonging to this Company, and have been found of advantage in that case.

Switzerland.

26. *F.* — 3) The Swiss Federal Railways have not adopted a uniform type of speed-indicator up to the present time; some branches of the Railway Administration prefer the Klose apparatus and others the Hasler. No other types have been tried, except the Teloc system used on the electric locomotives. The Klose apparatus records the instantaneous speed; the Hasler apparatus records the average speed over a period of twelve seconds. Finally the Teloc apparatus, made by Hasler, records the mean speed during the last second.

Yugo-Slavia.

27. *S. C. S.* — 3) We use apparatus of the Hausshælter system and are satisfied with it. We have not tried other systems, and do not

propose, at present, to make trials. It is unnecessary to describe the Hausshælter system, as it is well known.

Our appliances show the speed every six seconds and give the mean for twelve seconds.

QUESTION 4. — *Is the introduction of speed-recording devices left to your own initiative, or is this made compulsory by any regulations?*

Belgium.

1. *E. B.* — 4) It is not required by the Belgian State regulations.

Spain.

3. *A.* — 4) There are no regulations making the fitting of speed-indicators compulsory.

4. *N. E.* — 4) The installation of these appliances on the locomotives is not required by the regulations.

United States of America.

5. *E.* — 4) This is left to the initiative of the Railway System.

6. *S. R. S.* — 4) The installation of speed-indicating and recording apparatus is left to the initiative of the Company, and there are no regulations making it compulsory.

7. *B. & O.* — 4) Speed-indicators are not compulsory at present under the Government regulations, but they are fitted to the locomotives selected by the « Operating Department », with a view to recording and checking the speeds of our locomotives.

Great Britain and Ireland.

14. *M. G. W.* — 4) This is left entirely to our initiative; there are no regulations with regard to this.

Australia.

15. *N. S. W.* — 4) This is left to our initiative.

Indian Empire.

16. *N. W.* — 4) The installation of speed-indicating and recording apparatus is not made obligatory by regulations on this Railway System.

17. *B. B. C.* — 4) This is left entirely to our own initiative.

Greece.

18. *E. G.* — 4) The initiative of the Railway System.

19. *P. A. P.* — 4) The installation of speed-indicating and recording apparatus depends entirely on our own initiative.

Norway.

20. *E. N.* — 4) The installation of speed-indicators on the locomotives is not made compulsory by the regulations, but is left to the initiative of the General Management.

Holland.

21. *E. P. B.* — 4) The installation of speed-indicating and recording apparatus is left to our own intitiative.

22. *E. R.* — 4) It is not made compulsory by the regulations.

Sweden.

23. *E. S.* — 4) The method of installing is not laid down in the regulations.

24. *B.* — 4) Only those locomotives that run at over 60 km. per hour are required by regulation to be fitted with a speed-indicator.

25. *H. N.* — 4) By the statutes of the Swedish law it is laid down that all locomotives that run at over 60 km. (37.3 miles) per hour must be fitted with speed-indicators.

Switzerland.

26. *F.* — 4) Speed-indicators had already been adopted by private Railway Companies during the period 1880-1890. Since that period the installation of speed-recorders on the locomotives has been made obligatory by the Swiss Federal Railway Department.

Yugo-Slavia.

27. *S. C. S.* — 4) The apparatus should be fitted on the locomotive in a vertical position, and when taken down it should not be placed in a horizontal position till it has stopped. The apparatus is fitted in the locomotive cab (on the driver's side).

[621. 135.4 (01]

Investigation of the running of locomotives on curves,

According to Dr. Engineer H. UEBELACKER.

Figs. 1 to 16, pp. 888 to 909.

(*Organ für die Fortschritte des Eisenbahnwesens, 1903.*)

The object of following report is to make known to engineers who are not very conversant with German the theory established by Mr. Uebelacker on the investigation of the running of locomotives on curves. This investigation will always be one of actual interest on account of the wheel base which is often of such great length in locomotives of modern construction. We have put on one side the calculation of resistance to motion in a curve as being less useful in practice; on the other hand we have somewhat modified the method of explaining matters by making use of graphical processes rather than algebraical calculations. Motion in a curve is considered only as a uniform motion, but this seems to be all that is necessary in practice, unless very small curves are taken into account in which locomotives never run at any great speed and where the forces due to inertia are negligible. Practical examples only are dealt with by Mr. Uebelacker.

F. L.

* * *

GENERAL THEORY.

We will take for granted in what follows that the locomotive in running keeps its relative position in respect to the curve without producing undue bumping, etc., of the flanges against the rails.

Let us first consider the motion of a non radial axle AB (fig. 1), and we will begin by supposing that it does not refer to a driving axle.

Let V' be the real speed of the point A (of the centre line of the axle). Resolve this speed according to the centre line of the axle and the plane of the wheel. We shall thus get the resultants u and w'

Let ω be the angular velocity of the axle round the centre C of the curve, ρ the radius of the curvilinear centre line of the road.

We shall get

$$\omega = \frac{V'}{AC}$$

and on account of relation between similar triangles :

$$\frac{u}{V'} = \frac{AA_0}{AC}$$

from which

$$u = AA_0 \times \frac{V'}{AC}$$

or

$$u = x \,.\, \omega \tag{1}$$

In the same way may be found

$$w' = AC_0 \times \omega$$

in which

$$w' = \left(\rho + \frac{s}{2}\right) . \omega \qquad (2)$$

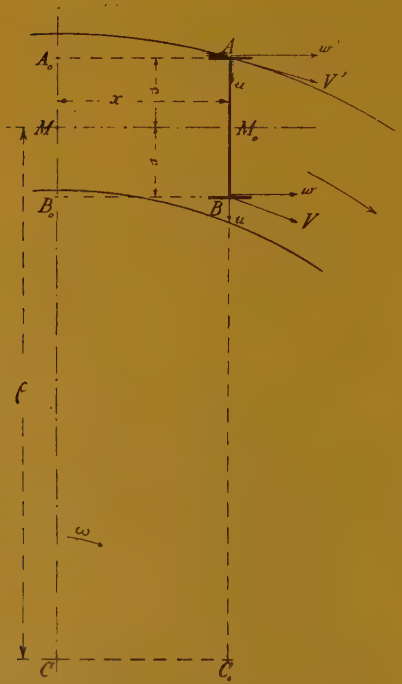


Fig. 1.

As regards the wheel B, it will be found for the component of V which follows the centre line of the axle, the same value as for wheel A, that is to say $u = x \cdot \omega$ and for the perpendicular component.

$$w = \left(\rho - \frac{s}{2}\right) . \omega \qquad (3)$$

We will suppose that the tyres are cylindrical, which will give a very small error and in many cases the hypothesis will correspond with the reality.

The wheels A and B being keyed to the same axle, it follows that a slipping action takes place at the contact of wheels and rails. The total velocity of the slipping will be equal to

$$w' - w = s \cdot \omega.$$

If the coefficients of friction at the contact of the two wheels are the same, it must be admitted that each wheel will slip on the rail with a velocity

$$v = \frac{s}{2} \omega;$$

so that in the last analysis action takes place from the frictional point of view as if the axle AB was submitted to a rotary motion ω round its middle point M_0 and a side motion $u = \omega \cdot x$ following the centre line of this axle. These two elementary displacements become a simple rotation ω round the point M situated on the perpendicular to the centre line of the axle at a distance

$$M_0M = \frac{u}{\omega} = x.$$

This reasoning may be repeated for a series of axles grouped rigidly in the framing, and it would be ascertained that for each of the axles action takes place as if the rotary motion ω took place round the point M, foot of the perpendicular dropped from the centre of the curve on to the centre line of the vehicle.

This point will be called *centre of friction* (1).

When slipping takes place, the frictional effort caused by the rail *on each wheel* cannot exceed fQ, f being the coefficient of friction and Q the load on the wheel. On each wheel therefore an effort fQ will be produced which will be directed tangentially to a circumference having for centre the centre of friction M (fig. 2).

(1) This title must not be confused with that of instantaneous centre of rotation. The instantaneous centre of rotation of all the axles is in this case the centre C of the curve.

The sum total of the forces fQ must be in equilibrium with the exterior forces acting on the vehicle. These exterior forces are for instance the guiding thrust of the rail on the first outside wheel, the guiding thrust of the inner rail on the back wheel, a transversal reaction at a point of the framing (bogie, pivot), etc.

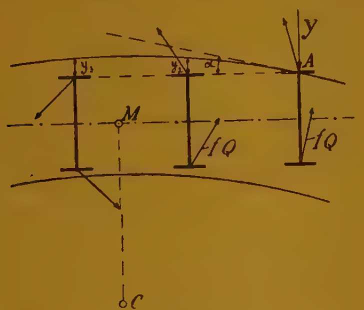


Fig. 2.

If this condition of equilibrium does not take place, this will evidently prove that the vehicle does not occupy a stable position, it will turn round the point A, the angle α will therefore be altered, until the point M, foot of the perpendicular dropped from the centre C on to the centre line of the vehicle occupies the required position.

When the vehicle occupies a stable position, the position of M is such that the sum total of the frictional forces fQ found, as explained above, is in equilibrium with the exterior reactions.

In the case where the vehicle circulates freely between the rails, that is to say, without reaction from the rail at the back, the frictional resultant fQ must pass longitudinally through the centre line of the first axle. This resultant is then equal to and directly opposite to the guiding thrust Y of the rail (fig. 2). M may easily be determined by proceeding graphically. This will be found out by trial; a first point M will be chosen situated close and in front of the back axle and then moved along the centre line of the vehicle until the resultant of the frictional forces passes through A. The point M which satisfies this condition will be the effective centre of friction.

As may be seen, *when the vehicle circulates freely in the curve the position of the centre of friction M is independent of the radius of the curve.*

To obtain an exact idea of the position of the vehicle in relation to the curve, it is only necessary to raise a perpendicular to the centre of friction M and to add a length equal to ρ to determine the centre C of the curve.

It is moreover easy to calculate the amount of play y_2, y_3 between the wheels and the outside rail.

In a general way, if y_1 represents the play between the first outside wheel and the rail, the play y_n of the wheel n situated at a distance d_n from the first axle will be given by the formula

$$y_n = y_1 + \frac{x_1^2 - x_n^2}{2\rho} \qquad (4)$$

or

$$y_n = y_1 + \frac{2x_1 d_n - d_n^2}{2\rho} \qquad (5)$$

or further,

$$y_n = y_1 + \frac{d_n^2 + 2x_n d_n}{2\rho} \qquad (6)$$

Figure 3 gives at once these relations. x_1 is the distance from the centre of friction M to the front axle.

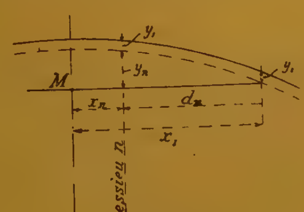


Fig. 3.

If the outside front wheel bears on the rail, then put $y_1 = 0$. The wheel n will touch the inside rail if $y_n = \sigma$, σ

being the total play between rails. We shall thus get (eq. 6) :

$$\sigma = \frac{d_n^2 + 2x_n d_n}{2\rho}$$

from which

$$x_n = \frac{\rho\sigma}{d_n} - \frac{d_n}{2} \qquad (7)$$

or further

$$x_1 = \frac{\rho\sigma}{d_n} + \frac{d_n}{2} \qquad (8)$$

The geometrical condition in order that the back axle may be *radial* is obtained by making $x_n = 0$.

$$\sigma \geqslant \frac{d_n^2}{2\rho} \qquad (9)$$

* * *

Let us now consider the case when the locomotive is working, and in which it develops a tractive effort Z (fig. 4).

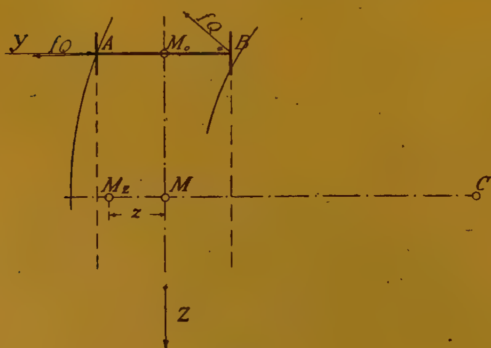


Fig. 4.

This tractive effort can only be obtained in consequence of the adhesion of the wheels on the rails; during the general slipping action which is produced in a curve, an additional slipping action will be produced at each wheel in the opposite direction to the tractive effort.

One of the velocities v and v' will therefore be increased, and the other reduced, according to a fixed value of a constant quantity for all the wheels, which are by supposition coupled, and equal to v_z.

We have seen that when the engine is running without steam (Z = 0) and that the first wheel only bears on the rails, the frictions at the contact of the rails increase as if the engine was subjected to a rotary motion ω round the centre of friction M, which is the foot of the perpendicular dropped from the centre of the curve on the centre line of the engine.

When the engine develops a tractive effort Z, we have then to consider a supplementary velocity of *translation* common to all the axles and which we have called v_z.

The combination of this translation action v_z with the rotary motion ω round M gives a rotary resultant ω round a point M_z situated on the perpendicular at M in the centre line of the engine and so that

$$z = MM_z = \frac{v_z}{\omega}.$$

This point M_z is the new centre of friction and is valid for the combination of all the coupled axles. It is situated towards the outside of the curve when Z is a tractive effort.

It would be forced towards the interior of the curve if Z was negative, and acting as a brake.

All the frictional forces at the contacts of the wheels will therefore be directed tangentially towards the circumferences round centre M_z.

As before, the resultant of all these frictional forces must balance the exterior reactions.

In the most simple case, the outside front wheel bearing alone on the rail and receiving from the latter a thrust Y, the resultant of frictions must pass through the middle of the front axle, point of intersection of the forces Y and Z.

The longitudinal component of this resultant will be equal to Z, and the

transversal component will be equal to Y.

If the resultant passes beyond M_0 the engine will turn round the bearing point of the wheel A and will approach the outside rail, at the same time the distance M_0M will decrease and the conditions of the problem will be changed. In this case therefore the position is not stable.

The contrary will happen if the frictional resultant passes beyond M_0. *The stable positions are characterised by the condition that the resultant of frictions* (tangential in relation to M_z) *passes through* M_0.

It is easy to see that there are an infinity of points M_z which satisfy this condition of stability. They are situated on a curve like that shewn in figure 5, and which is asymptotical relatively to a perpendicular to the centre line of the engine in the middle of the whole wheel base.

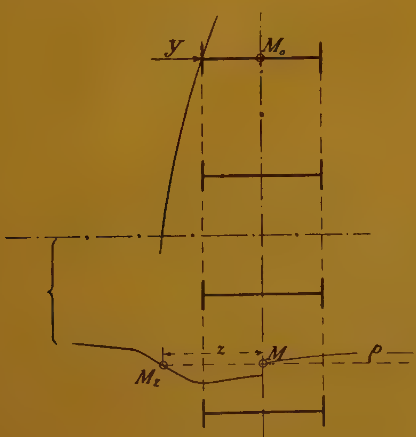


Fig. 5.

At each point M_z there is evidently a different corresponding tractive effort Z.

There is therefore in the last analysis a point M_z, centre of friction, which satisfies all the conditions of equilibrium.

If the value of Z is fixed, it will be necessary to find the position of the point M_z by trial.

It is as well to point out that the geometrical position of the points M_z as well as the determining of the point M_z corresponding to the tractive force Z *are independent of the radius of the curve.*

The only condition for determining the centre of frictions M_z is that it gives a frictional resultant passing through M_0 of which the longitudinal component is equal to Z.

The preceding is evidently only valid when the outside front wheel alone bears on the rail.

The centre M_z being determined, a perpendicular M_zM is dropped on the centre line of the engine and extended a length ρ so as to reach the position of the centre of the curve C.

Having fixed all these details, the exact position of the locomotive relative to the road can be established and the amount of play of all the wheels be determined as previously pointed out.

* * *

When an inside back wheel bears on the rail, the *stable* position of the engine

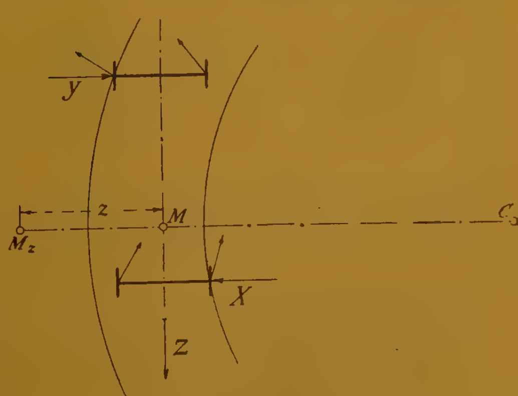


Fig. 6.

is evidently well defined *a priori,* for it depends on the total play ρ and the ra-

dius of the curve. The centre of friction will be found on the perpendicular dropped from the centre C on to the centre line of the engine. It will be found on the centre line ($z = 0$) when the engine is running without steam and at a distance z determined for $Z \neq 0$. In this case the reactions Y and X of the outside and inside rails would be found in resolving according to the direction of these lines the transversal component of the resultant of frictions.

* * *

When we consider the influence of the reactions of the rail on the locomotive, Y or X, the transversal component G of the frictional force fQ must not be neglected. This component has generally to be deducted from the reaction Y or X, but it may happen that it exceeds the reaction itself. The action of the rail, instead of being directed towards the interior of the roadway, is then directed in the opposite direction, and algebraically would then have a *negative* value. This case happens frequently with back axles.

The negative value of a reaction of the rail is evidently limited to the frictional effort fQ itself.

The reactions of the rails are interesting to know, not only to judiciously fix the dimensions of the parts of the locomotive, but also to guard against the risks of derailing.

* * *

Slipping action in the particular case when the wheels control the direction.

Under the influence of the guiding reaction Y and X, the wheel is induced to roll on parts that are fixed at a greater angle directed towards the hollow of the tyre flange until equilibrium takes place between the forces acting at the point of contact in the part of the inclined plane under consideration. The slipping action of the wheel no longer takes place in a horizontal plane, but in an inclined plane set at an angle α (fig. 7).

The velocity of transversal slipping u becomes $\dfrac{u}{\cos\alpha}$.

The slipping velocity v remains as before.

This slipping in the inclined plane will then take place according to the resultant of these two velocities $\dfrac{u}{\cos\alpha}$ and v.

The frictional effort will consequently be no longer fQ but

$$f(Q\cos\alpha + Y\sin\alpha)$$

and should be found in the direction of the resultant of $\dfrac{u}{\cos\alpha}$ and of v.

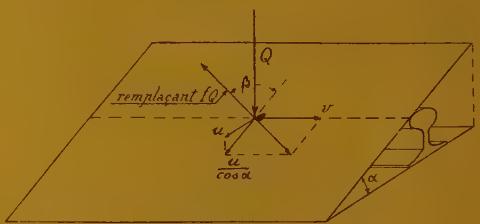


Fig. 7.

To obtain transversal equilibrium, we shall therefore have to write down that

$$f(Q\cos\alpha + Y\sin\alpha)\cos\beta$$

balances

$$Q\sin\alpha - Y\cos\alpha$$

or

$$f(Q\cos\alpha + Y\sin\alpha)\cos\beta = Q\sin\alpha - Y\cos\alpha$$

The slipping will therefore take place towards the bottom as soon as.

$$Q\sin\alpha - Y\cos\alpha > f(Q\cos\alpha + Y\sin\alpha)\cos\beta$$

or

$$Y < Q\frac{\tan\alpha - f\cos\beta}{1 + f\tan\alpha\cos\beta} \qquad (10)$$

When Y is greater than this value, derailing is to be feared.

The value to be considered for angle α is 60° for the normal section of flange, angle β is determined as soon as the centre of friction M or M_z is known.

If possibilities of derailing are considered, an unfavourable hypothesis may be constructed by making $\beta = 0$. The formula (10) thus becomes by putting $f = \frac{1}{5}$

$$Y = 5.7\, fQ \tag{11}$$

It should be pointed out that Y is in this case the reaction of the rail on the wheel without taking into account the slipping of the latter. With these hypotheses, the total reaction is

$$R = Y - fQ \cos \beta$$

and if we put $\cos \beta = 1$ it is found that derailing is to be feared, as soon as the total reaction on the wheel reaches the value.

$$R = 4.7\, fQ \tag{12}$$

Investigation of some types of locomotives from the point of view of running on a curve.

I

Arrangement type A.

Locomotive with four coupled axles without a carrying axle.

We will suppose the axles to be equally loaded and at equal distances of 1 m. 5 (4 ft. 11 in.) from each other so as to give a total wheel base of 4 m. 5 (14 ft. 9 1/8 in.)

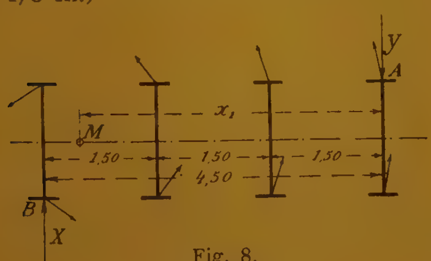


Fig. 8.

The width *s* between rails is equal to 1 m. 5 (4 ft. 11 in.)

We will first of all consider the positions the locomotive would take when running *without steam.*

First case. — When the front outside wheel only bears on the rail. We have seen above that when $Z = 0$, the centre of friction M is placed on the centre line of the locomotive and that its position, which is independent of the radius of the curve, is determined by the condition that the resultant of the forces fQ must pass through A. By trial, it is found that in this particular case M is situated at a distance $x_1 = 4$ m. 01 (13 ft. 1 7/8 in.) from the front axle.

The resultant of the frictional forces is directly opposed to Y and equal to

$$Y = 4.396\, fQ$$

The total thrust of the rail at A will be

$$R_A = Y - G_1 = 3.415\, fQ$$

G_1 being the transversal component of the frictional force fQ on the wheel 1.

The guiding action of the rail, R_A, *remains constant, whatever may be the radius of the curve, so long as the wheel* A *alone makes contact with the outside rail.*

Second case. — The back wheel B makes contact with the inside rail at the same time as the front wheel A bears on the outside rail.

This begins to happen in the first instance at a particular radius of the curve given by the equation

$$y_4 = \sigma = \frac{2x_1 d_4 - d_4^2}{2\rho} \tag{5}$$

if we take $\sigma = 0.035$, we find for the limiting radius

$$\rho = \frac{2x_1 d_4 - d_4^2}{2\sigma} = \frac{2 \times 4.01 \times 4.5 - \overline{4.5}^2}{0.07}$$
$$= 226 \text{ metres.}$$

For radii below 226 m. (11.3 chains),

the wheel B continues to bear on the rail, but the centre of friction M, foot of the perpendicular dropped from the centre of the centre line of the locomotive moves towards the front.

We find for instance for $\rho = 180$ m. (9 chains), $\sigma = 0.035$.

$$x_1 = \frac{\rho\sigma}{d_1} + \frac{d_1}{2} = 3\text{m}.\ 65\ (11\text{ ft. } 11\ 11/16\text{ in})$$

The centre of friction M determined in this way will serve to trace out all the frictional forces fQ, their resultant will be found and then resolved according to the lines of the reactions Y and X.

$$Y = 4.31\, fQ$$
$$X = 0.647\, fQ$$

The transversal components of the frictional forces in A and in B are respectively

$$G_A = 0.98\, fQ$$
$$G_B = 0.750\, fQ$$

So that the total reactions of the rail at A and at B are respectively

$$R_A = (4.31 - 0.98)\, fQ = 3.33\, fQ$$
$$R_B = (0.647 - 0.750)\, fQ = -0.103\, fQ$$

It will also be found that in a general way the requisite condition for the back axle to bear on the inside rail is

$$\rho\sigma \leqslant x_1 d_1 - \frac{d_1^2}{2} \quad \text{(formula 5)}$$

or in the case we are considering :

$$\rho\sigma \leqslant 7.92$$

It will be seen therefore that when $\rho = 180$ m., the condition under which the back axle may bear on the inside rail is

$$\sigma \leqslant \frac{7.92}{180} = 0\text{ m. } 044\ (1\ 3/4\text{ inches}).$$

* * *

Let us now consider the case in which the locomotive works. We will take for the tractive effort Z the value 6.2 fQ.

As we are dealing with a locomotive with 8 coupled wheels, the swivelling action should be produced when $Z = 8\, fQ$, the chosen value 6.2 fQ shews therefore the margin left to avoid the swivelling action.

We will consider different cases as before :

First case. — The front wheel A bearing alone on the rail with the back part of the engine running freely between the rails. We have already seen that in this case a centre of friction M_z has to be considered which is situated towards the outside of the curve and at a distance z from the centre line of the locomotive. The resultant of the frictional forces fQ must pass through the middle of the front axle in order that the position we are considering may be stable. With $Z = 6.2\, fQ$ we find

$$z = 2\text{ m. } 33\ (7\text{ ft. } 7\ 3/4\text{ in.})$$
$$x_1 = 3\text{ m. } 64\ (11\text{ ft. } 11\ 5/16\text{ in.})$$

The reaction Y equal and opposite to the frictional resultant is equal to

$$Y = 2.899\, fQ$$

the transversal component G_1' of the frictional force at the wheel A is

$$G_1' = 0.915\, fQ$$

so that the total reaction of the rail on the wheel A is

$$R_A = 1.984\, fQ$$

We may point out that the position of the centre of frictions M_z relative to the locomotive being independent of the radius of the curve, the reaction R_A is also independent of the radius of the curve. This happens as long as the front wheel A only bears on the rail.

It will be seen therefore that the reaction R_A of the rail is smaller when the engine is working.

As before, the exact position of the engine between the rails may be determined for each radius, and also from

what radius the back wheel B bears on the inside rail.

If we put $\sigma = 35$ mm. (1 3/8 inches) we find that

$$\rho = \frac{2x_1 d_4 - d_4^2}{2\sigma} = 179 \text{ m. (8.95 chains)}$$

it is starting from this radius that the back wheel B comes into contact with the inside rail (second case).

Before proceeding to the investigation of this case, let us see how the tractive force is distributed on the different driving axles. Each wheel develops as tractive effort, a force equal to the longitudinal component K of the frictional force fQ. If we mark with an accent the values of K relative to the outside wheels, we shall find that the tractive efforts at each axle K + K' have different values shewn in the table below for different total values of the tractive force Z.

Z (fQ)	z	K + K' *a*) In units fQ; *b*) In percentages of the total effort.			
	Metres.	Axle 1.	Axle 2.	Axle 3.	Axle 4.
2.616	0.75 *a*)	0.344	0.500	0.807	0.967
	b)	*13.2*	*18.1*	*30.9*	*37.8*
4.065	1.125 *a*)	0.521	0.754	1.246	1.544
	b)	*12.8*	*18.5*	*30.6*	*38.1*
5.049	1 50 *a*)	0.710	1.025	1.657	1.657
	b)	*11.2*	*20.0*	*32.9*	*32.9*
6.197	2.325 *a*)	1.042	1.411	1.903	1.841
	b)	*16.8*	*22.8*	*30.6*	*29.8*

The distribution is therefore unequal between the four axles, for the different values under consideration of the tractive force, it is the back axles which are nearest to the centre of friction which have the largest share. This difference is greatest for the smaller values of Z.

For the normal value Z = 6.2 fQ the front axle gives out only 16.8 % of the total effort.

As it is advantageous, especially to reduce the frictional losses in the transmission of power from one wheel to the other, that the main driving axle should deal with the greatest amount possible of the total effort, it would be an advantage for this axle not to be placed too far away from the centre of friction. According to this therefore, the main driving axle should be chosen amongst the back axles, whilst if a carrying axle is necessary, its logical place is in front.

The figures given in the preceding table are valid for all the radii of

$$\rho = \infty \text{ to } \rho = 179 \text{ m. (8 95 chains).}$$

Second case. — *The wheel* B *bears on the inside rail.*

The condition for this case to happen is

$$\rho\sigma \leqslant x_1 d_4 - \frac{d_4^2}{2} \qquad (5)$$

If ρ and σ are determined, the value of x_1 is found. z will have to be found by trial, so that the corresponding centre of friction M_z gives a resultant, the longitudinal component of which is equal to Z. The transversal component will be resolved according to the lines Y and X and by this means the value of these reactions will be arrived at.

The total reactions R_A and R_B will be found by subtracting the transversal components G_A, G_B.

$$R_A = Y - G_A,$$
$$R_B = X - G_B.$$

II

Arrangement type B.

Locomotive with four coupled axles and pony truck in front.

We will again suppose that all the wheels are equally loaded (fig. 9).

Let e be the linear displacement of the pony truck in relation to the centre line of the engine. In order that the pony truck may transfer to the main frame the guiding action it receives from the rail, it is necessary to make use of

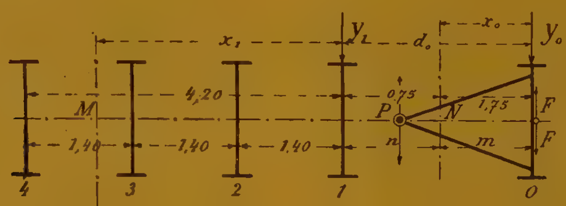


Fig. 9.

a centering arrangement. This is achieved by means of springs, inclined planes or else by suspension links

Before attempting the calculations relative to running in a curve, it is expedient to examine the nature of the centering effort.

In a general way, if F represents this force, we shall have

$$F = \varphi(e)$$

φ representing a definite function of e.

In the following calculations we will suppose F proportional to e.

$$F = k \cdot e$$

If ε represents the angular displacement, we obtain

$$e = m\varepsilon$$

the angular displacement is itself represented by the expression

$$\varepsilon = \frac{x_1 + d_0 - x_0}{\rho} \qquad (13)$$

x_1 being the distance from the centre of friction M of the coupled batch of wheels to the front driving axle, x_0 the distance from the centre of friction N of the pony truck, d_0 the distance between the front driving axle and the carrying axle.

In the case we are supposing

$$F = k \cdot e = k \cdot m \frac{x_1 + d_0 - x_0}{\rho} \text{ units } fQ. \quad (14)$$

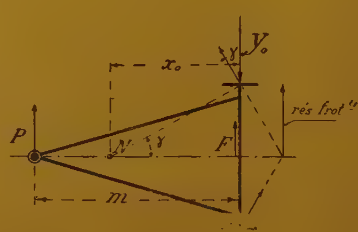


Fig. 10.

If we now consider the pony truck (fig. 10) we find that its centre of fric-

tion must be such that the corresponding frictional resultant is in equilibrium at P round the first front outside axle.

The reaction Y_0 is thus determined and is equal to

$$Y_0 = P + F + 2G_0$$

G_0 being the transversal component of the thrust of the front wheel on the rail.

The total reaction of the rail will be

$$R_0 = P + F + G_0$$

All the particulars relating to the question have thus been found.

As F is known, the linear displacement of the pony truck is known; it is the same for the angular displacement $\varepsilon = \frac{e}{m}$ and as (fig. 11)

$$\varepsilon = \frac{x_1 + d_0 - x_0}{\rho} \qquad (15)$$

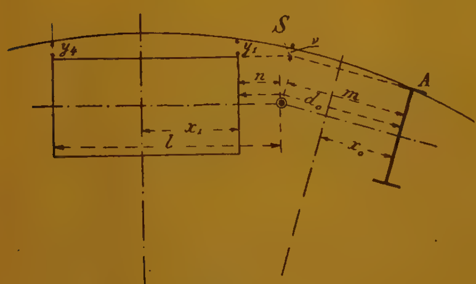


Fig. 11.

it may be seen that the corresponding radius ρ of the curve is determined.

$$\rho = \frac{x_1 + d_0 - x_0}{\varepsilon} \qquad (16)$$

The exact position of all the axles between rails may thus be determined.

Draw AS perpendicular to the carrying axle, the plane of the outside wheels will meet it in S. The distance ν from this point to the outside rail will be

$$\nu = \frac{2x_0 m - m^2}{2\rho} \qquad (17)$$

And on applying formula (5) we find:

$$y_1 = \nu + \frac{2(x_1 + n)n - n^2}{2\rho}$$

$$= \frac{2x_1 n + 2x_0 m + n^2 - m^2}{2\rho} \qquad (18)$$

and likewise

$$y_4 = \frac{2x_1 l + 2x_0 m + n^2 - m^2 - d_4^2}{2\rho} \qquad (19)$$

or further

$$y_4 = y_1 + \frac{2x_1 d_4 - d_4^2}{2\rho} \qquad (20)$$

* * *

The following investigation shews that as far as the thrust on the rail by the different groups of wheels is concerned, there are only three possible cases :

1° The carrying axle only bears on the outside rail, the others circulating freely;

2° The carrying axle and the first coupled axle bearing simultaneously on the outside rail;

3° The carrying axle bears on the outside rail and the last coupled axle on the inside rail.

a) *The locomotive running without steam.*

First case. — *The carrying axle only bearing on the outside rail.*

The group of coupled axles running freely and without developing any tractive effort, the centre of friction corresponding to it will be situated on the centre line of the locomotive ($z = 0$).

Let M be its position (fig. 12). At this centre M the frictional forces fQ correspond, the position and direction of which are well determined.

The position of the locomotive being considered stable, the resultant of the frictional forces corresponding to M should balance with the reactions, P at the real or imaginary pivot of the pony truck and the centering force F, which are transferred to the main framing.

These two forces P and F being in the same direction, it will be immediately seen that the resultant of the frictional forces which they should balance must pass *between* P and F. The only points M that it is necessary to consider, at least

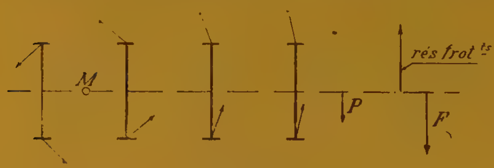


Fig. 12.

as far as the first case is concerned, are those included between two points : M_P, M_F. The first giving a resultant passing through P, the second a resultant passing through F.

It therefore any point M in this part is chosen, there will be a definite corresponding resultant which if resolved along the directions of P and F, the values of these reactions will be found at once.

If the pony truck (fig. 10) is considered, it will be found that the frictional forces must be in equilibrium with the reaction P. The frictional resultant is equal to

$$2 \cos \gamma \,.\, fQ$$

Its leverage is $\frac{s}{2}$ tan γ and its moment round the centre of axle is

$$M = s \,.\, \sin \gamma \,.\, fQ$$

In order that equilibrium may be maintained therefore, it is necessary that

$$Pm = s \,.\, \sin \gamma \,.\, fQ$$

It will be immediately seen that *the value of P is limited to*

$$P_{max} = \frac{s}{m} \,.\, fQ \qquad (21)$$

This value corresponds to the frictional forces at the wheels of the front axle parallel to the centre line of the engine. The corresponding centre of friction is therefore found at the centre line of the axle $x_0 = 0$.

The carrying axle is therefore *radial*.

The ground to take into consideration through which the frictional resultant passes becomes therefore smaller and only reaches from the point giving a component P equal to the maximum $\frac{s}{m} \cdot fQ$ and the centre line of the carrying axle.

In the case with which we are dealing, it is found that when $x_1 = 3.09$, $Pm = 1.5\, fQ$ from which $P = 0.857\, fQ$ and $x_0 = 0$. The carrying axle is therefore radial.

For each group of values x_1 x_0 there is a definite corresponding radius of the curve which is given by the formula (14) :

$$\rho = \frac{km}{F}(x_1 + d_0 - x_0)$$

this radius also depends therefore on the value of the coefficient of proportionality k. It should also be pointed out that the same component P can also be balanced round the centre line of the carrying axle by the frictional forces obtained in starting from a centre of friction placed in front of the carrying axle at a distance $- x_0$. This is clearly shewn in figure 13. N and N' are symmetrical in relation to the centre line of the carrying axle.

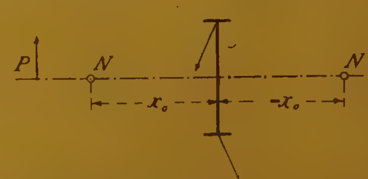


Fig. 13.

It will be seen therefore that to each value of x_1 will correspond definite values of P and F and two equal values and contrary signs for x_0.

For the value $x_1 = 3.09$ we find $x_0 = 0$; this case constitutes therefore the crossing point from the positive group of values to the negative group. It will also be seen that when x_0 becomes negative, the radius ρ of the corresponding curve increases. In this way the following series of values are found :

$x_1 =$	3.02	3.05	3.07	3.08	3.09	3.08	3.07
P	0.211	0.493	0.680	0.829	0.858	0.829	0.680
F	2.420	2.230	2.100	2.040	1.985	2.040	2.100
x_0	2.95	1.07	0.591	0.369	0	— 0.369	— 0.591
G_0	0.969	0.820	0.619	0.476	0	— 0.476	— 0.619
y_0	4.569	4.363	4.018	3.821	2.843	1.917	1.542
R_0	3.600	3.543	3.399	3.345	2.843	2.393	2.161
ρ	$1.86\,k$	$3.52\,k$	$4.14\,k$	$4.47\,k$	$4.85\,k$	$5.10\,k$	$5.13\,k$
ρ when $k = 100$ . . .	186	352	414	447	485	510	513
— $k = 70$ . . .	130	246	290	313	340	357	359
y_1 when $k = 100$. . .	0.0332	0.0083	0.0050	0.0038	0.0022	0.0016	0
— $k = 70$. . .	...	0.0118	0.0072	0.0055	0.0032	0.0021	0
y_4 when $k = 100$. . .	(0.0542)	0.0196		0.0131	0.0109		0.0081
— $k = 70$. . .	(0.0775)	0.0281		0.0187	0.0155		0.0114
y_3 when $k = 100$. . .	...	...		...	...		...
— $k = 70$. . .	(0.0819)	0.0306		0.0204	0.0171		0.0130

Second case. — *The carrying axle and the first coupled axle bear on the outside rail.*

This case occurs when the thrust P at the pivot can no longer be balanced by the frictional forces developed at the pony truck wheels, that is to say, when P has its maximum value (for $x_1 = 3.09$).

$$P_{max} = \frac{s}{m} \cdot fQ$$

y_1 being nothing, the formula (18) gives:

$$x_0 = -\frac{n}{m} x_1 + \frac{m^2 - n^2}{2m}$$

or in the case we are considering :

$$x_0 = -0.4286\, x_1 + 0.7143$$

It will be consequently seen that for the second case, x_0 is always negative. *The carrying axle bears therefore on the outside rail inversely to the usual way; its angle of thrust will always be negative.*

The calculation is easily made as follows : x_1 being fixed upon, a definite value of x_0 results on account of the above relation.

x_0 being determined, the reaction at the pivot P which must balance the fric-

tions of the carrying wheels is immediately found.

The resultant of the frictions of the group of coupled wheels, which is kown, since x_1 is fixed *a priori*, should therefore be resolved according to the line Y_1, P which is determined in magnitude, and F. The forces Y_1 and F are therefore determined.

The total reaction of the rail at the carrying axle will be as before

$$R_0 = P + F - G_0$$

the reaction R_1 at the first coupled axle will be

$$R_1 = Y_1 - G_1$$

G_1 being the transversal component of the frictional effort at the first outside coupled axle.

We find that the second case ceases to happen, the radius of the curve increasing when P + F, forces applied to the pony truck, make a sum which is precisely equal to 2 G_0. The reaction of the outside rail limits itself then to G_0 and therefore it is no longer necessary for the wheel to bear on the rail, that is to say, $y_0 = 0$. It is found that this limiting case happens when $x_1 = 3.461$ and $\rho = 14.1\ k$, namely if $k = 100$, ρ 1.410 m. (70 1/2 chains) and if $k = 70$, ρ = 986 m. (49.3 chains).

The following results are found :

$x_1 =$	3.10	3.20	3.30	3.40	3.461
x_0	— 0.615	— 0.656	— 0.701	— 0.741	
P	0.663	0.643	0.629	0.610	
F	2.00	1.66	1.35	1.04	
G_0	0.634	0.656	0.675	0.704	
R^0	2.03	1.65	1.29	0.941	
R_1	— 0.775	— 0.143	+ 0.423	+ 0.990	
ρ	5.43 k	6.70 k	8.41 k	11.2 k	14.1 k
When k = 100	543	670	841	1120	1410
When k = 70	380	469	589	784	986
y_4 when k = 100	0.0078	0.0069	0.0060	0.0040	

Third case. — The inside back wheel bears on the rail at the same time as the outside wheel of the pony truck bears on the outside rail.

If we look back to the first case, we see that for small radii the value of y_4 can exceed the total play between rails σ, for y_4 increases when the radius decreases.

If Z = 0, σ = 35 mm. (1 3/8 inches) it will be seen that the third case happens for radii less than 212 m. (10.6 chains).

A new unknown quantity comes into play; this is the reaction X at the back wheel.

The back axle bearing on the inside rail, we get

$$y_4 = \sigma = \frac{2x_1 l + 2x_0 m + n^2 - m^2 - d_4^2}{2\rho}.$$

We have therefore a relation between x_0, x_1 and $\rho\sigma$.

On the other hand, we have as before :

$$F = km \cdot \frac{x_1 + d_0 - x_0}{\rho} \cdot fQ$$

The method of resolving will be the same as before. If ρ and σ are given, a value of x_0 will be chosen which will lead immediately to the determination of G_0 and of P.

The forces P and F balance, round the inside back wheel, with the frictional resultant of the group of coupled axles. The value of x_1 corresponding to x_0 is found from the first formula above. The frictional resultant is therefore determined, it balances three parallel forces x_4, P, F, of which one, P, is absolutely determined; x_4 and F are therefore also determined.

If x_0 has been well chosen, the centering force F which is found is that which proves the formula

$$F = km \cdot \frac{x_1 + d_0 - x_0}{\rho} \cdot fQ$$

The problem is resolved therefore by trial.

When $Z = 0$, several hypotheses have been made :

I . . . $\rho = 180$ m. $\sigma = 35$ mm. $k = 100$.
II . . . $\rho = 180$ m. $\sigma = 50$ mm. $k = 100$.
III . . . $\rho = 180$ m. $\sigma = 35$ mm. $k = 70$.

The following results are found :

HYPOTHESIS	I	II	III
x_1	2.30	2.81	2.57
x_0	2.84	2.95	2.07
P	0.219	0.212	2.92
F	1.90	2.29	2.04
G_0	0.966	0.969	0.939
R_0	3.09	3.471	3.271
R_4	+ 0.723	— 0.314	+ 0.287
y_1	0.030	0.0334	0.0239

Examination of the results shews that in the sharpest curves, the guiding reaction R_0 on the carrying axle is smaller than in curves of larger radius (in the case $Z = 0$). This must be attributed to the intervening action of the back axle. The reaction R_4 on the latter is moreover small : $+ 0.723\ fQ$ when $\rho = 180$ m. and $\sigma = 35$ mm. If the play σ is greater on account of the wear of the flange, the locomotive can take a position which approaches more to that of free circulation, that is to say, x_1 is greater than given above. The carrying axle then receives nearly the whole of the guiding action.

$$\left.\begin{array}{l} R_0 = 3.471 \\ R_4 = -0.314 \end{array}\right\} \text{when } Z = 0. \quad k = 100.$$

It results from the examination of the values of x_1 (2.30 — 2.81 — 2.57) that the thrust of the back axle is only possible when the flanges of the coupled axles are thinned.

If for hypothesis III we suppose the tyres of the third coupled axle are not thinned, this axle bears on the rail and we find for $Z = 0$.

$$\begin{array}{ll} x_1 = 2.45 & R_3 = +1.376 \\ x_0 = 1.72 & y_1 = 0.0186 \\ P = 0.368 & \rho = 180 \\ F = 2.290 & \sigma = 0.035 \\ G_0 = 0.903 & k = 70 \\ R_0 = 3.561 & \end{array}$$

As may be seen, when the direction is influenced by the third driving axle, the total reaction R_0 at the carrying axle is bigger and R_3 is much bigger than R_4. The third axle is in this case the driving axle and its coming into action as directing axle should be avoided on account of the wear on the tyres and to prevent wearing of the bearings of the boxes.

The influence of the centering con-

stant k comes into evidence when comparing the results corresponding to the hypotheses I and II. It will be seen that when k is smaller, or which comes to the same thing, when for the same value of F there is a larger corresponding deviation of the carrying axle, as well as an increase of the total play σ (hypothesis II) the value of x_1 increases so that the intervening action of the coupled axle to guide becomes smaller.

$$R_0 = 3.27 \qquad R_4 = +0.287$$
$$\text{when } \sigma = 35 \text{ mm.}, \qquad k = 70.$$

whilst

$$R_0 = 3.09 \qquad R_4 = +0.723$$
$$\text{when } \sigma = 35 \text{ mm.}, \qquad k = 100.$$

In a general way the equation

$$F = k \, . \, m \frac{x_1 + d_0 - x_0}{\rho}$$

shews that if k is proportional to ρ the same value of F will correspond to the same values of x_1 and of x_0.

If therefore a new value k' is adopted we find the series of forces F, R_0, etc., by displacing the diagram of these forces and making the radii abscissæ, in such a way as to make the same forces correspond with the radii increased in the proportion $\frac{k}{k'}$.

b) *The locomotive exerting a tractive effort.*

The same method should be adopted in the case of an engine exerting tractive effort. It will be seen as before that the reaction R_0 becomes smaller, but only for radii less than 350 m. (17 1/2 chains).

For longer radii, R_0 is distinctly greater when the locomotive works than when it runs without steam. It is only for radii above 640 m. (32 chains) that uniformity tends to re-establish itself. This is due to the tractive effort producing an extension of the engine, and so consequently the first case is extended to the above mentioned radius (640 m.).

If the *centering force* F *is constant* (centering with inclined planes for instance) the equation

$$F = ke$$

fails. The distance x_1 is independent of ρ and is determined by taking into account the fact that the frictional resultant must resolve itself in two components, of which one F is known in magnitude and position and the other P is given by its direction.

P is therefore also constant and in consequence x_0, G_0, R_0, etc., whatever may be the radius of the curve.

Only the angular displacement ϵ varies with ρ.

If the values found are introduced in the equation

$$y_1 = \frac{2x_1 n + 2x_0 m + n^2 - m^2}{2\rho}.$$

it will be seen that if the numerator is *positive*, y_1 will only be zero when $\rho = \infty$ so that the second case can never occur.

If, on the contrary, the numerator is *negative*, it will be the first case that can never happen and x_1 must be calculated from the study of the second case.

For curves of small radii the thrust on the rail is made simultaneously by three axles.

Consideration of the preceding should be given in determining the angle of the inclined centering planes.

III

Arrangement type C.

Locomotives with four coupled axles with Krauss bogie.

We will suppose equal loading of all the axles.

The first axle 0 is free to move like a pony truck round a pivot that is fixed relatively to the main framing. The coupled axle to which it is connected can move transversely.

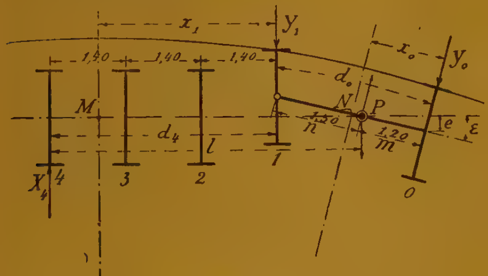


Fig. 14.

In running in a curve the first coupled axle must turn according to the direction of the curve, and it will be seen that the force necessary to accomplish this rotation can only start from the outside rail, for the reaction of the working of the bissel is directed towards the outside and cannot therefore influence this rotation.

It will be seen therefore that *with a Krauss bogie, the two front axles always bear simultaneously on the outside rail.*

This principle distinguishes it from the ordinary bogie with two axles which turns round a fixed pivot and in which the second axle does not necessarily bear on the outside rail.

From the geometrical point of view however these two bogies agree.

As will be seen from the following investigation of this kind of arrangement, the back axle bears on the inside rail for nearly every radius, which brings about a small reduction in the guiding reactions at the front wheels.

For curves of small radius, the frictional centre of the group of coupled axles approaches the centre, it is therefore necessary to considerably thin the flanges of the intermediate wheels.

There are therefore only two cases to consider:

First case. — *When the back coupled axle does not bear on the rail.*

If the main framing is considered, it will be seen that the only forces to which it is submitted are the frictional forces at the wheels, from a definite frictional centre M and the reaction P at the bogie pivot. The frictional centre M is found by trial and should be such that it gives a frictional resultant (for axles 2, 3 and 4) passing through the pivot P.

The reaction P balances this resultant.

As concerns the bogie, its centre of friction N will be situated in the middle of the distance d_0 between the two front axles. This happens because these two axles always bear on the outside rail. The frictional resultant for the bogie is thus easily determined, it being composed of two frictional forces fQ of the axle O having N for centre and of two frictional forces of axle 1 having M for centre. The reactions Y_0 and Y_1 are therefore determined by the condition that they must balance the reaction P at the pivot and also the frictional resultant.

We get as before (formula 15) and figure 14

$$e = n \cdot \frac{x_1 + d_0 - x_0}{\rho}$$

$$y_4 = \frac{x_1 + d_0 - x_0}{\rho} \cdot n + \frac{2x_1 d_4 - d_4^2}{2\rho} \qquad \text{(form. 20)}$$

And if we put

$$n + d_4 = l$$

and take into account that

$$x_0 = \frac{d_0}{2}$$

we find

$$y_4 = \frac{1}{2\rho}(2x_1 l + d_0 n - d_4^2)$$

expression which gives the displacement of the last coupled axle.

According to the preceding calculations, we see that, for the first case, the reaction at the pivot P and the reactions R_0 and R_1 of the rail on the two first axles are independent of the radius of the curve.

We find when

$$Z = 0 \qquad x_1 = 3\text{ m}.45 \qquad x_0 = 1\text{ m}.35$$

$$Z = 6.2 \quad \begin{cases} x_1 = 3\text{ m}.21 & x_0 = 1\text{ m}.35 \\ z = 2\text{ m}.11 & \end{cases}$$

Second case. — *When the back axle bears on the inside rail.*

This case occurs in starting from the radius which gives

$$y_4 = \frac{1}{2\rho}(2x_1 l + d_0 n - d_4^2) = \sigma$$

or

$$2\rho\sigma = 2x_1 l + d_0 n - d_4^2 \qquad (22)$$

The value of x_1 being that which is valid for free circulation, it is found when

$$Z = 0 \qquad \rho\sigma = 12.9$$
$$Z = 6.2 \qquad \rho\sigma = 11.6.$$

For the values of $\rho\sigma$ below these figures, the back axle bears on the inside rail. It is not therefore from ρ and σ taken alone, but from their product $\rho\sigma$ that x_1 depends, whilst for the arrangement type B the values ρ and σ act independently.

The value $\rho\sigma$ being given, the corresponding value of x_1 is given by the equation (22). The resultant of the frictional forces on the axles 2, 3, 4 is therefore determined in magnitude and direction, and resolved according to P and X_4, for the remainder the process will be as before.

It will be found

When Z = 0 :

$\rho\sigma$	6.3	7.5	9.0	10.00	11.5	12.5	12.9
x_1	2.30	2.50	2.77	2.95	3.20	3.38	3.45
P	1.05	1.20	1.43	1.56	1.69	1.74	1.78
R_4	+1.55	+1.21	+0.633	+0.222	—0.290	—0.607	—0.706
R_0	1.727	1.812	1.93	2.01	2.08	2.11	2.12
R_1	1.15	1.22	1.33	1.39	1.46	1.48	1.50

When Z = 6.2 :

$\rho\sigma$	6.3	9.0	10.4	11.6
x_1	2.30	2.77	3.00	
z	1.93	1.98	2.03	
P	0.418	0.677	0.779	
R_4	+0.914	+0.278	—0.044	—0.327
R_0	1.38	1.52	1.58	1.62
R_1	0.566	0.743	0.810	0.854

As σ only varies by steps, the product $\rho\sigma$ is proportional to ρ in the space between these steps.

The following table gives the normal values of σ according to the figures of the Bavarian State Railways:

Radius, in metres		from 180 to 300	300 400	400 500	500 600	600 700	700 800	800 900	Above 900
Extra width, in millimetres. . .		25	20	16	12	9	6	3	0
Total play when the play in the straight line is :	a) 10 mm.	35	30	36	22	19	16	13	10
	b) 25 mm.	50	45	41	37	34	31	28	25
Value of $\rho\sigma$ when the play in the straight line is :	a) 10 mm.	from 6.3 to 10.5	9 12	10.4 13	11 13.2	14.4 13.3	11.2 12.8	10.4 11.7	>9
	b) 25 mm.	from 9 to 15	13.5 18	16.4 20.5	18.5 22.2	20.4 23.8	21.7 24.8	22.4 25.5	>22.5

It is as well to point out that the value of σ which we are considering is made up of the normal play when the road is straight, which may vary from 10 to 25 mm. (3/8 to 1 inch), and of the extra width in the curve.

The field in which cases 1 and 2 may be applied can be determined by means of this table.

When $Z = 0$ we have seen that the first case is only possible when $\rho\sigma > 12.9$ which only happens for radii between 497 and 500 m. (between 24.85 and 25 chains), between 586 and 600, 680 and 700 as well as above 1 290 m. (between 29.3 and 30, 34 and 35 as well as above 64 1/2 chains).

When $Z = 6.2$ the first case only happens for radii between 387 and 400, 446 and 500, 527 and 600, 725 and 800, 892 and 900 and above 1 160 m. (between 19.35 and 20, 22.3 and 25, 26.35 and 30, 36 1/4 and 40, 44.60 and 45 and above 58 chains).

The divergencies are therefore greater when the locomotive works than when it is running without steam, which is clear from what has been stated previously.

It is moreover when the back axle (first case) is running freely that R_0 and R_1 have their greatest value, for their direction is then only controlled by two axles.

The smaller $\rho\sigma$ is the more the front axles are freed as concerns the guiding action, whilst R_4 increases. Generally speaking the variations of R_0 and R_1 are small. The variation in steps of $\rho\sigma$ brings about a discontinuous variation of R_0 and of R_1.

In the case we are dealing with, R_0 is about equal to 1.4 R_1, thus as we have previously seen, we can to some extent modify this distribution between the two front axles, it only being necessary to choose the dimensions m, n and d_0 accordingly.

IV

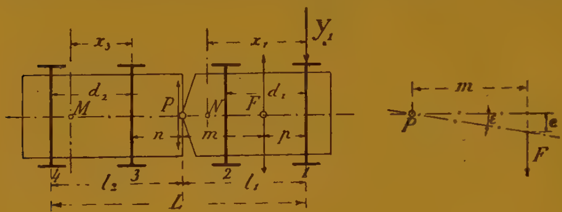
Arrangement type D.

Locomotive type « Mallet ».

The present form of locomotive with two motive truck arrangements was designed by Mallet and Rimrott. It consists of a main frame carrying the boiler and engine driver's cab and which is attached to the two back axles.

The two front axles are connected to a secondary framing which turns round a pivot P situated behind it, approximately in the centre of the length of the locomotive.

Axles 1 and 2 are coupled, as are also axles 3 and 4,



$d_1 = 1$ m. 75 $\quad n = 1$ m. 15

$d_2 = 1$ m. 75 $\quad m = 2$ m. 025

$l_1 = 2$ m. 90 $\quad p = 0$ m. 875

$l_2 = 2$ m. 90 $\quad$ L $= 5$ m. 80

Q $= 7$ t. 1

Fig. 15.

and form two independent groups with motive power; the first group is worked by the L. P. cylinders, the second by the H. P. cylinders (fig. 15).

The front truck is kept central in its mean position by means of strong spiral springs. The directing reaction of the rail on the front outside wheel is transmitted to the main frame (centering force F) by the action of the spring.

The main framing is under the influence of a second action, that of the pivot P.

As the front truck on account of its small mass would run in an irregular manner under the influence of the reciprocating masses, it is necessary for the springs to possess a sufficient initial tension.

Let F be this initial tension which increases for each centimetre of linear deviation by k kgr. The arrangement of springs is such that the spring on the side of which the deviation is taking place alone comes into play.

The value of the centering force F will then be

$$\mathrm{F} = F + 100\,ke \tag{23}$$

On the other hand, the angular deviation ε is equal to

$$\varepsilon = \frac{\mathrm{L} - d_2 + x_3 - x_1}{\rho} \tag{24}$$

In addition we have

$$\varepsilon = \frac{e}{m} \tag{25}$$

By combining these three equations we find

$$\mathrm{F} = F + \frac{100\,.\,k\,.\,m\,(\mathrm{L} - d_2 + x_3 - x_1)}{\rho} \tag{26}$$

and

$$\rho = \frac{100\,.\,k\,.\,m\,(\mathrm{L} - d_2 + x_3 - x_1)}{\mathrm{F} - F} \tag{27}$$

We will take $F = 500$ kilograms and $k = 330$ kilograms.

When the front axle alone bears on the outside rail.

In the type of locomotive under consideration, the tractive effort Z which is supposed to be always equal to 6.2 fQ (4 driving axles) is distributed between the two motive trucks. We will suppose that the work is distributed equally between the two trucks and that they each develop a tractive effort equal to 3.1 fQ.

The tractive effort due to the front truck is applied to the pivot P.

In making the calculation we will proceed as follows : A definite value will be chosen for x_3. The corresponding centre of friction gives a frictional resultant the transversal component of which shall be resolved according to the direction P and F, thus giving the values of these reactions. The longitudinal component will give, in case this happens, the tractive effort.

P and F being determined, the value of x_1 will be looked for, this giving a frictional resultant which, combined with P, F and Z, if the case occurs, which will pass through the point of contact of the front wheel with the outside rail. Y_1 will thus be determined.

The equation (27) gives the radius ρ of the curve.

The distances of the axles to the outside rail will be calculated as before (arrangement type B). It will be found

$$v = \frac{2x_1 l_1 - l_1^2}{2\rho}$$

and we shall have

$$y_4 = v + \frac{2(x_3 + n) l_2 - l_2^2}{2\rho}$$

or

$$y_4 = \frac{(x_1 + x_3) L - l_1^2 + 2n l_2 - l_2^2}{2\rho} \quad (28)$$

We thus find when Z = 0 the following results :

x_3 =	1.35	1.40	1.45	1.50	1.52	1.57	1.60
F	1.37	1.24	1.08	0.922	0.856	0.694	0.572
P	—0.560	—0.321	—0.042	+0.232	+0.354	+0.643	+0.848
x_1	2.31	2.155	2.005	1.87	1.81	1.67	1.56
G_1	0.950	0.941	0.937	0.930	0.925	0.914	0.981
R_1	2.96	2.80	2.62	2.40	2.29	2.04	1.83
Y_1	3.910	3.741	3.557	3.330	3.215	2.918	2.731
ρ	179	222	290	400	470	781	1.440
y_2	0.0145	0.010	0.007	0.0045	0.0036	0.0019	0.0009
y_4	0.0309	0.0236	0.0170	0.0117	0.0097	0.0055	0.0028

It will thus be seen that with the type of engine under consideration and when Z = 0, the back axle never bears on the inside rail when $\rho > 180$ m.

It is found that when Z = 6.2 fQ

x_3	1.00	1.03	1.05	1.10	1.15	1.20	1.25
z_3	1.44	1.44	1.435	1.43	1.425	1.420	1.410
F	1 04	1.00	0.965	0.885	0.797	0.704	0.611
P	—0.860	—0.777	—0.712	—0.560	—0.395	—0.225	—0.055
x_1	...	3.20	2.87	2.35	2.04	1.855	1.74
z_1	...	2.99	2.60	1.99	1.63	1.43	1.35
G'_1	...	0.819	0.840	0.883	0.919	0.935	0.946
R_1	...	1.948	1.930	1.857	1.775	1.611	1.480
Y_1	...	2.767	2.770	2.740	2.674	2.546	2.426
ρ	...	178	224	329	458	650	1.005
y_2	...	0.0228	0.0155	0.0078	0.0043	0.0026	0.0015
y_4	...	0.0404	0.0281	0.0130	0.0091	0.0058	0.0036

As regards the position of the centres of friction of the two trucks, it will be seen that when Z = 0 as well as when Z = 2 × 3.1 fQ, axle 4 is nearer to the radial position than axle 2. The centre of friction is situated at no great distance in front of the back axle, as on a locomotive with rigid axles.

On the other hand, x_1 and x_2 are naturally smaller in the case with which we are dealing; for instance when ρ = 329 m. (16.45 chains) and Z = 2 × 3.1 fQ, the expression $x_3 + n + l_1$ which is that corresponding to rigid axles will be equal to 5 m. 15 (16 ft. 10 3/4 in.), whilst x_1 is only equal to 2 m. 35 (7 ft. 8 1/2 in.).

It results from this that G_1 and G_2 are in fact negligible.

Examination of results shews that when the radius of the curve increases, axle 2 approaches the rail and axle 4 places itself more and more radially. It is also noticed that x_1 varies within greater limits than x_3. It follows that the back truck is more stable and the oscillations in the running of the front truck are only transmitted to a small extent to the main framing, its inertia not being taken into account.

When the radius of the curve ρ increases progressively, the directing action R_1 has a decreasing influence, first rapid and then slower when Z = 0. When the locomotive works, R_1 becomes smaller, and also decreases, though slowly, as the radius of the curve increases. The ordinate z from the centre of friction is greater for the front truck, on account of the greater value of x; and varies between 2.99 and 1.35 for x_1 placed between 3.20 and 1.74 whilst the divergence is hardly 1.42 for the values of x_3.

On account of the higher value of the supplementary speed of slipping (with Z ≠ 0) and from what has been said previously, the pivoting takes place much more easily at the wheels of the front truck than at those of the back one. It is therefore advisable to give to the H. P. cylinders of the back truck a greater proportion of the motive work.

In addition to the hypotheses made as regards the centring constants F and k, two additional hypotheses have been put forward :

Hypothesis II . . $F = 100$ kgr. $k = 330$ kgr.
— III . . $F = 500$ kgr. $k = 250$ kgr.

The reduction of F and k has the effect that a definite value of the directing reaction R_1 corresponds with smaller radii, or, which comes to the same thing, equal radii correspond to smaller reactions R_1. It is not however advisable to go too far in reducing the centering constants on account of the disturbing movements of the front truck.

We may further remark that when x_3 increases beyond a certain value, it happens that the reaction F given by the calculation is smaller than the initial tension F. The divergence e is in that case nil and corresponds to a radius $\rho = \infty$.

In the example, we are dealing with this case happens :

when Z = 0

$$x_1 = 1.42 \qquad x_3 = 1.64$$
$$F = 0.416\, fQ = 500 \text{ kgr.}$$

when Z = 2×3.1 fQ

$$x_1 = 1.55 \qquad x_3 = 1.39$$
$$F = 0.416\, fQ = 500 \text{ kgr.}$$

In the construction of recent locomotives of this type, the front truck is provided in addition with a carrying axle. In this way the development of the tractive effort in curves for the front truck is improved and a better stability is obtained as far as the disturbing action of the mechanism is concerned.

V

Arrangement type E.

Locomotive with two coupled axles and front bogie.

This type of engine is nearly always used for express engines, and in America even for very powerful goods engines.

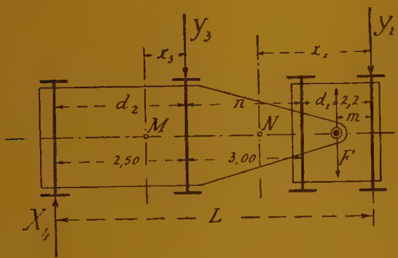


Fig. 16.

The rotation of the bogie can be accomplished without resistance, but its transversal displacement develops a centering force which is produced either by the action of springs, or by a component of the weight acting on a link arrangement. The springs are generally fixed in tension, and act in the centre of the distance between the two axles or a little behind this point.

The side play is limited by stops to 30 mm. (1 3/16 inches).

First case. — *When the front axle only bears on the rail.*

The centre of friction M is determined by the condition that the resultant of the frictional forces passes through the bogie pivot. The reaction at the bogie pivot is determined on account of it.

The centre of friction N of the bogie is determined by the condition that the resultant of the total forces of friction at the bogie and of the reaction F passes through the point of contact of the front wheel with the rail which gives the reaction Y_1.

All the values thus found are independent of the radius of the curve.

We find when $Z = 0$:

$$x_1 = 2.307 \qquad x_3 = 2.225 \qquad F = 1.206$$
$$G_1 = 0.952 \qquad Y_1 = 3.394 \qquad R_1 = 2.442$$

and when $Z = 3.1\, fQ$

$$x_1 = 2.394 \quad x_3 = 1.89 \quad Z = 1.76 \quad F = 0.731$$
$$G_1 = 0.954 \qquad Y_1 = 3.144 \qquad R_1 = 2.19.$$

The transversal displacement e of the bogie is calculated by means of the relation which connects e and F.

If we suppose that the springs have an initial tension $F = 500$ kgr. and that they have a deflection of 10 mm. per 330 kgr., it is found that with a centring force $F = 1\,206$ fQ the displacement $e = 0.0287$. Knowing e the calculation of y_3 and y_4 can be made and the exact position of the locomotive between the rails is thus found.

An axle supposed to be fixed at the distance of the pivot of the bogie would have as distance to the rail

$$v' = \frac{2x_1 m - m^2}{2\rho}.$$

If this axle formed part of the main framing its distance from the rail would be

$$v = v' - e.$$

And on account of the formulae previously established we immediately find

$$y_3 = v' - e + \frac{2\,(n + x_3)\,n - n^2}{2\rho}$$
$$= \frac{2x_1 m + 2x_3 n + n^2 - m^2}{2\rho} - e$$

and

$$y_4 = v' - e + \frac{2\,(n + x_3)\,l - l^2}{2\rho}$$
$$= \frac{2x_1 m + 2x_3 l - l^2 - m^2 + 2ln}{2\rho} - e$$

We find for the hypothesis put forward above:

$$y_3 = \frac{13.16}{\rho} - 0.0287$$

$$y_4 = \frac{15.56}{\rho} - 0.0287$$

The limit of the first case is furnished by the condition :

$$y_3 = 0$$

We find

$$\rho \geqslant \frac{13.16}{0.0287} = 457 \text{ m.}$$

always following the hypotheses as put forward above : Z = 0, F = 500.

For radii of greater length we come to the

Second case. — *When the front axle of the bogie and the front or back coupled axle bear stimultaneously on the outside rail.*

A centre of friction will be chosen for the group of coupled axles, to this will correspond a frictional resultant which is resolved in directions F and Y_3 which will thus be determined.

The centre of friction of the bogie will be found as previously. The value e of the displacement of the bogie will be calculated, and the corresponding radius of the curve determined by the formula

$$\rho = \frac{2x_1m + 2x_3n + n^2 - m^2}{2e} \qquad (y_3 = 0).$$

We thus find when Z = 0 the following values :

x_3 = . .	2.30	2.35	2.40	2.45
F.	1.073	0.970	0.862	0.752
x_1	2.33	2.35	2.37	2.39
R_1	2.37	2.32	2.26	2 20
R_3	−0.638	−0.407	−0.172	+0.070
e.	0.0239	0.0202	0.0163	0.0123
ρ.	560	670	841	1 128

and when Z = 3.1 fQ :

x_3	1.94	2.00
z	1.76	1 75
F	0.681	0.641
x_1.	2 40	2.41
R_1	2.15	2.14
R_3	— 0.768	— 0.659
e	0.0096	0.0082
ρ	1270	1530

It will be seen that according to the value of x_3, which is positive, that axle 3 bears on the outside rail before axle 4 can do so. This supposes that the tyres of axle 3 are of normal section. If the flanges of axle 3 are reduced in section, the first case is limited to the moment where the 4th coupled axle bears on the outside rail.

This is *case 2b.* It will be seen that when Z = 0, it can only happen when ρ ⩾ 542 m.

The calculation is made in a similar way, axle 4 simply taking the place of axle 3.

It is found when

$$Z = 0 \quad . \quad F = 500$$

when

$$\rho \geqslant \frac{15.56}{0.0287} = 542 \text{ m}$$

x_3 = . .	2.50	3.50	4.00
F	1.22	1.11	1.067
x_1	2.305	2.325	2.33
G_1	0.955	0.955	0.955
R_1	2.452	2.292	2.369
R_4	0.689	1.647	1.787
e	0.0293	0.0252	0.0239
ρ	586	884	1 070

Third case. — *When axle 4 bears on the inside rail.*

It is found that $y_4 = \sigma = 35$ mm. in supposing

$$Z = 0 \qquad F = 500$$

when

$$\rho \geqslant \frac{15.56}{0.0637} = 245 \text{ m.}$$

When $Z = 3.1\ fQ$ we should have had

$$\rho \geqslant \frac{13.40}{0.0465} = 288 \text{ m.}$$

The calculations are made as before. When axle 4 bears on the rail and axle 3 circulates freely, the smallest value of x_3 is

$$x_3 = \frac{d_2}{2} = 1 \text{ m. } 25$$

which corresponds to radii $R = 175$ m. when $Z = 0$ and $\rho = 244$ m. when $Z = 3.1\ fQ$.

It is found when

$$Z = 0, \quad F = 500, \quad \sigma = 35 \text{ mm.}$$

$x_3 =$	1.25	1.80
F	1.061	1.141
x_1	2.335	2.320
R_1	2.37	2.41
R_4	+ 0.203	— 0.021
e	0.0234	0.0264
ρ	175	216

For radii less than 175 m. and 244 m. (8 3/4 and 12 1/5 chains) the directing action passes from axle 4 to axle 3.

Fourth case. — *When axle 3 bears on the inside rail.*

The calculation has been made when $Z = 3.1\ fQ$ when $\rho < 244$ m. in taking $\sigma = 35$ mm.

We have for instance when

$$x_3 = 1.20 \quad z = 1.82 \quad F = 1.144 \quad x_1 = 2.32$$
$$R_1 = 2.66 \qquad R_3 = 1.623 \qquad e = 0.0255$$
$$\rho = 166 \text{ m. } 5$$

If the tyres of axle 3 had reduced flanges, this change of action from axle 4 to axle 3 would naturally not take place.

[624. (01]

Suldbach Tests : A Swiss study of bridge action.

Figs 1 to 10, p. 913 to 916.

(*Engineering News-Record.*)

A remarkable study of bridge action carried out in Switzerland throws valuable light on questions of continuity due to interaction of the separate elements of truss bridge framework. It affords the clearest picture of the behavior of a pony-truss structure that has ever been obtained experimentally, and it defines the interrelation of the various parts of the floor construction and their relation to the bottom chord and crossframe construction virtually for the first time. No publication of the data or the results has yet been made, although the tests were carried out three years ago. The following abstract of the investigation is based on a manuscript copy of the report, supplied by M. Rôs, secretary of the Swiss Bridge Builders and Structural Fabricators Association, which carried out the work as part of the ambitious research-test program outlined in *Engineering News-Record* of 30 June, 1921, p. 113.

Bridge data. — The bridge tested is a single-track railway span, one of a pair on double-track line of the Lötschberg Railway over the Suldbach near Mülenen. It is a pony-truss parallel-chord span 63 ft. 4 1/2 in. long center to center of end bearings, comprising eight panels of 7.92 feet each. The trusses are 7.89 feet deep center to center of web connections, and 8.18 feet deep over all. The roadway width center to center of trusses is 16.42 feet and the two lines of stringers are spaced 5.90 feet apart. The panel length of the bottom lateral system is two truss panels. The truss web system comprises posts at all panel points and crossed diagonals in each panel. The rails rest on wooden cross-ties on I-beam stringers.

The truss chords are single-web T sections consisting of a web plate 14×1/2 inch, two angles 3 3/16×3 3/16×3/8, and one or two cover plates 14 inches wide. The posts are star sections of four angles 2 3/4×2 3/4×3/8 inch; the compression and counter diagonals two 7-inch channels or two T's back to back, the tension diagonals two 7 or 9-inch flat bars. The floorbeams are 20-inch plate girders connected to the posts by triangular bracket plates extending the full height of the posts, 22 inches wide at the base (24 inches in the case of the end post) by 3/8 inch thick, spliced into the floor-beam webs. The stringers are single 12 3/4 inch I-beams.

Test methods. — All the tests were made under *static* loading, using a single concentration of known amount. For vertical loading, a single-axle test load of 24.9 metric tons (27 440 lb. per wheel) was provided. The test axle was arranged at mid-length of a four-wheel truck, with vertical adjustment enabling the full weight of the truck to be concentrated on it when in position for test. Horizontal loading of the top chord was provided by a straining tackle with spring-scale dynamometer (fig. 1), which

could be put in place between the top chords and by which a horizontal force of 4 408 lb. acting to pull the top chords together was applied.

Fig. 1. — Stress-test arrangements on Suldbach bridge.

At left, strain yoke for lateral loading of top chord; test truck in rear. At right, extensometers, deflection recorders, and clinometers on stringers.

Measurements of stresses, deflections and slopes were made on various members of floor, trusses and laterals, usually under a succession of different positions of the test load. In most instances the results were plotted in the form of influence lines (showing the variation of effect at a given point under a traveling load, plotted along the travel of the load). The deflection and slope measurements checked closely with the stress measurements, but in some cases the former served to bring out a particular effect more prominently. A sufficient number of extensometers was used at any one measuring point (compare figure 1, right-hand view) to give the stress at the principal corners of the cross-section, so that the true mean stress could be determined as well as the amount of vertical and lateral bending and torsion. The torsion of various members was determined directly by clinometer measurements, which were also used in determining the change of slope of a point on floorbeam, post or stringer during the travel of a load.

The tests with horizontal force applied to the top chord gave little or no information additional to that furnished by the vertical-load measurements. Tests with simultaneous horizontal and vertical loading confirmed the applicability of the rule of superposition. With a single exception, the following summary reports only vertical-load measurements.

Stringer continuity. — Some typical results of the stringer measurements are shown in figure 2. Curves are given of flange stress at the third-point of the third panel, and of angular deflection at points in the second and third panels close to the floorbeam between these panels; all the curves are drawn as influence lines. They exhibit the continuity of the bottom chord at first glance. The stress curve, which is rather more symmetrical and consistent than those obtained in some of the other panels, is

remarkable in indicating the effect of the general deflection of the span and the floorbeam deflection; reverse bending does not begin as soon as the load passes off the stringer, but only when the load has passed some distance beyond the first tie in the next span. The sketch of the stringer connection to the floorbeam given in the figure shows that the attachment is not superior in rigidity to that ordinarily used.

The measurement of slope at two cross-sections in adjoining panels, these sections being on opposite sides of the same floorbeam, brings out the continuity of the stringers even more clearly, though the difference between the curves for the two points is not explained by the data.

The curve of stress at center of gravity of the stringer, derived from the measured flange stresses and shown by dash-and-dot lines in figure 2, theoretically indicates participation of the stringers in the transmission of bottom-chord stress, but the effect is considered to be within the limits of experimental error. The effect of floor tension was found more definitely in the lateral bending of the floorbeams and in the stresses of the bottom lateral system.

With respect to the latter, the specimen stress influence lines given in figure 3 are instructive. In all three cases they show a resultant tension, especially pronounced when the load is in the two panels of the laterals nearest the point of measurement. As these curves were taken under vertical loading, the stress in the laterals is due to the elongation of the chords and to the spreading of the bottom chords near the loaded panels by the stretch of the bottom flanges of the floorbeams. Probably the stretch of the bottom flange of the stringer while bending under load also plays a part in creating tension in the laterals. It is to be borne in mind that the laterals are riveted to the bottom flanges of the floorbeams at the intersection points, which connection resulted in introducing a number of apparent anomalies into the lateral as well as the floorbeam stresses.

The pronounced bending in the members of the lateral system and the inequality in stress distribution between the two diagonals of a single panel (see lower curves in figure 3) also invite attention.

Beam and chord behavior.

Floorbeam stresses. — Continuity of the floor is further demonstrated by the measurements of floorbeam flange stresses, one set of which is plotted in figure 4, an influence line of stress of the floorbeam three panels from the expansion end. It will be seen very pronounced bending exists in the floorbeam for some time after the load has passed off the tributary stringer panels. The four separate curves shown by light, full, and dotted lines respectively represent the two edges of upper and lower flanges respectively, and the heavy full lines (derived from the others) refer to the middle of the flange width. The stresses in the opposite edges of either flange give clear evidence of considerable sidewise bending of the floorbeam, reversing under the load.

Clinometer measurements near the ends of the floorbeams were also made during the passage of the test load; one influence line is included in figure 4. It gives evidence that there was downward bending in the floorbeam while the load remained within two panels of it, and thus tends to show that the truss deflection played a negligible part in its effect on the behavior of the floor, and that the continuity of the floor itself was the dominant feature.

Crossframe action. — Two sets of observations, out of a large number, on the behavior of the crossframe (floorbeam, posts and bracket gussets) are reproduced in figure 5, together with a

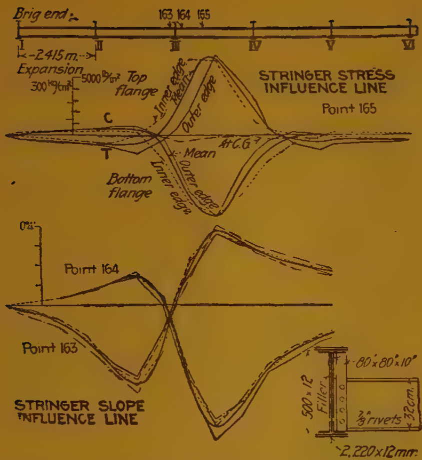


Fig. 2. — Stringer stresses; influence lines for stress and slope.

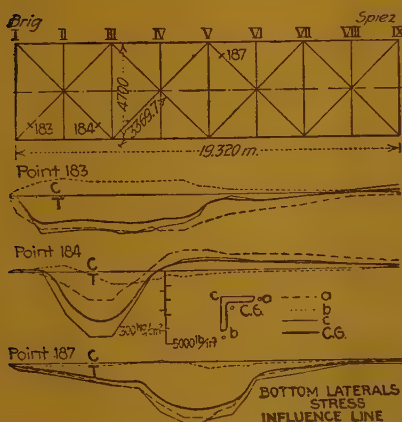


Fig. 3. — Stresses in bottom laterals.

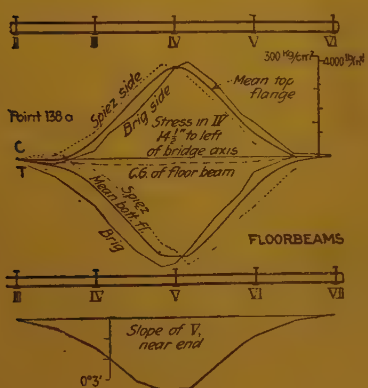


Fig. 4. — Floorbeam stress and slope influence lines.

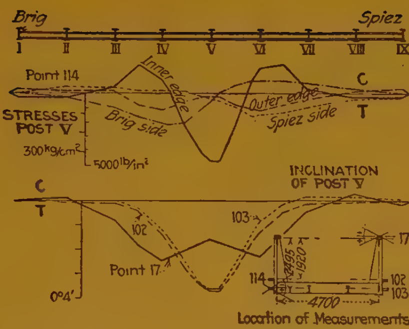


Fig. 5. — Bending in post bracket plates.

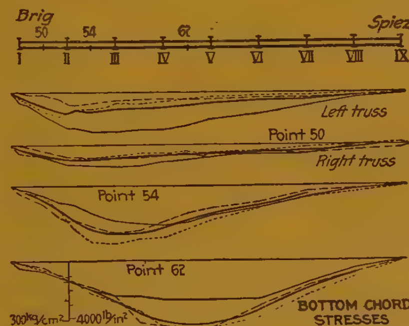


Fig. 6. — Vertical and lateral bending in bottom chord.

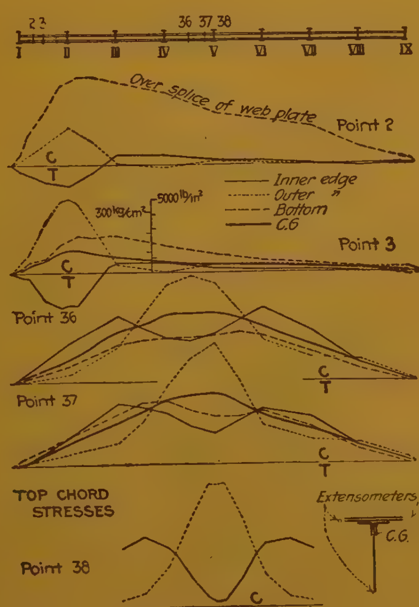


Fig. 7. — Top-chord stress influence lines.

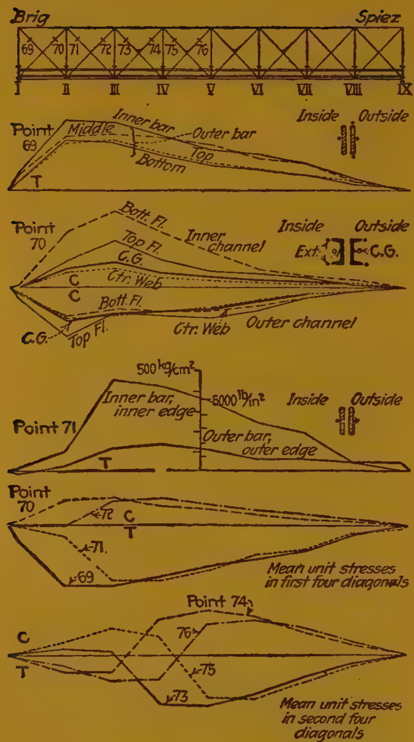


Fig. 8. — Distribution of stress between two web systems.

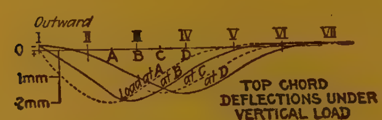


Fig. 9. — Top-chord bending under vertical load; elastic continuity.

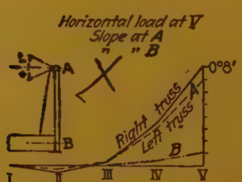


Fig. 10. — Clinometer readings on cross-frames under horizontal load at midspan.

location diagram. They refer to the mid-span frame (*V*). The influence diagram of stresses in the posts and brackets at track level (point 114) shows very pronounced bending in the post, of reversed direction, as the load moves along the span. While the major bending is that in the plane of the floorbeam, with pronounced tensile stress along the inner edge of the bracket plate when the frame in question is loaded, there is also a decided bending in the longitudinal direction, reversing as the load passes the crossframe.

Slope measurements by clinometer made at the top and at two points near the base of the crossframe, as indicated in the location diagram, bring out the influence of the lateral deflecting tendency of the top chord upon the crossframe action. The slopes near the base of the frame are very regular, and quite in accord with the floorbeam bending as shown in figure 4; the slope at the top, however, decreases as the load comes on the floorbeam of the crossframe in question, evidently due to an outward pressure exerted by the top chord tending to resist the distortion of the crossframe. Apparently this action accounts for the tensile stress developed at the inner edge of the bracket plate, shown in the stress diagram.

Chord stresses. — While the chord-stress measurements show diagrams that in general check closely with what would be expected, a number of interesting anomalies appear.

In the case of the bottom chord, decided differences in the behavior of the corresponding members of the two opposite trusses are found in certain cases. The end panel presents such a case, as shown by the curves for point 50 in figure 6. While the mean tension is pretty much the same for both chords, the chord of the left truss has two pronounced irregularities, one being an abnormal excess of stress when the load

is near the first panel point, and the other a very decided upward bending of the chord, shown by high tension in the upper edge of the chord web-plate, which persists for all positions of the moving load. The former effect may arise from irregularities of tie bearing, but the other, lying in the truss itself, is possibly due to a kink in the member which tends to straighten out under tension. Near mid-span the bottom chord appears to behave more normally, with slight downward bending as might be expected to result from the general deflection of the span. There is little lateral bending shown either here or in the end panel, each of the measuring points being at the center of a panel.

Top chord irregularities.

Much greater irregularities appear in the top-chord stresses, figure 7. At point 2, the extensometer at the bottom edge of the chord web was located over a web splice, and here a highly abnormal compressive stress appears. There is obvious lateral bending, the member bending inward presumably by the effect of the crossframe distortion, though the maximum does not occur until the load reaches the first panel-point. At mid-panel, point 3, the lateral bending is even more pronounced. However, the greatest lateral bending (compare points 36, 37 and 38) occurs at a panel point (38), where it approximately doubles the extreme-fiber compression. At the quarter point and middle of the panel (37 and 36) the lateral bending amounts to only about 50 % increase of the mean stress. The general downward bending of the span is indicated by the deficiency in stress at the bottom edge of the web at 36, and a pronounced secondary-stress effect possibly representing the shear deflection in the loaded panels is revealed by the downward bending appearing at 37. These curves are typical of the others obtained from the top-chord measurements.

Diagonals. — The double web system makes the diagonal stress measurements of peculiar interest. As the compression and counter diagonals are stiff and the tension diagonals flexible (two flats), unequal distribution of stress between the two systems might be expected. From the measurements plotted in figure 8 it appears that any differences of this sort are much smaller than the differences between inner and outer bar of a member and the bending and twisting stresses in the channels of the compression diagonals. However, after elimination of these, by taking mean stresses computed for the center of gravity of the member, as is done in the two lower diagrams, it appears that the tension diagonals take considerably higher stresses than the compression diagonals in the end panels, and somewhat higher stresses even in the center panels, where the same section is used (two T's, 4 3/4× 2 1/2×3/8 inch).

Lateral bending of top chord. — The preceding curves are influence lines. Bending of the top chord is shown in a more readily intelligible way by the geometric plots, figures 9 and 10. Figure 9 is for vertical load, figure 10 for horizontal load. For the former the lateral deflections are plotted, so that the curves represent the actual shape of the chord (in plan view) to greatly exaggerated scale. As in each of the four curves only one point is loaded, the chord deflection is controlled by the crossframe action. With load at mid-panel, the lateral ordinate of the top chord is greatest at mid-panel, though the deflecting force is applied through the frame at the panel point. The curves show a remarkably perfect degree of elastic action in the top chord, and give complete assurance that the top-chord action and stress distribution with respect to lateral bending

proceed strictly in accordance with elastic hypotheses. In fact, the lateral continuity of the chord is great enough to cause the chord to pull the cross-frames at some distance from the loaded region outward from normal position.

More complete proof of this latter point is furnished by the slopes of the posts (for half the span) under horizontal load. Figure 10 plots the curve for a load of 4 400 lb. lateral pull on the top chord at mid-span. In this case the only vertical action exerted is that due to the reactions resulting from the elastic continuity of the floor which is bent down at the frame where the transverse pull is applied, by the downward bending of the floorbeam. If this action, however, were controlling in the transmission of top chord deflections, the greater slopes at the points of outward bending would occur in the lower portion of the posts, whereas the diagram shows that the slope at top of post is greatest throughout the span.

Conclusions.

Analysis of results. — Exhaustive analysis of the results of the measurements by comparing them with theoretical calculations yielded some noteworthy results.

The twisting tendency of the stringers, due to the outward thrust of the lower fibers of the tie and the concentration of tie load on the inner flange, was small, the two effects almost balancing. The maximum eccentricity of tie load (inward) was found to be less than 1/2 inch. Study of the stringer continuity indicated that slackness of the connections to the floorbeams reduced by one-half the negative moment at the ends of the panel, even after allowing for yielding of supports.

Reduction of stringer moment below the simple-span moment, mainly by continuity and only in very minor degree by rail distribution, averaged about 12 1/2 % at mid-span and 31 % at one-sixth the span from the support; but as side thrust and torsion effects increased the extreme-fiber stress from vertical bending alone by amounts of 28 to 49 %, it was concluded that it is justifiable to neglect the continuity as compensation for the neglect of thrust and eccentricity of loading. The end shear was found to be slightly reduced (by 1/4 to 1/3). The results were interpreted as indicating that if full continuity be counted on, the stringer connections should be detailed accordingly, to be capable of carrying a negative moment of 38 % of the center moment and an end shear three-fourths that of a simple span; while if only partial continuity is to be taken into account, as with ordinary detailing, a negative moment only half as great, or 19 %, and a shear on the floorbeam rivets of two-thirds the simple-span shear is to be counted. The floorbeam rivets are subjected to a moment which is at least equal to the stringer end shear multiplied by the distance from connection rivets to floorbeam web.

Floorbeam concentrations were found to be considerably reduced by the continuity. For load directly over the floorbeam, the concentration appeared to average about three-fourths of the axle load, about 13 % going to each adjacent floorbeam, while slight upward reactions appeared at the next two floorbeams. Other effects, however, increased the floorbeam stress to that corresponding to about 86 % of the actual load. The analysis of crossframe action was interpreted as indicating that the resistance of the bottom chord and of the laterals has little effect on the behavior of the frame. The end constraint of the floorbeams, according to the test, was relatively small.

Comparison of the truss stresses with those obtained by three methods of calculation—shear divided equally between tension and compression diagonals, shear divided in proportion to area, and

precise calculation according to relative deflections—indicated that all three are fairly applicable, the variations of measurements equaling or exceeding the differences between the several methods. The bottom-chord stresses are uniformly less than the calculated ones, doubtless due to the chord action of the bottom lateral system and the stringers.

Floorbeam bending by the differential movement of stringers and bottom chord is broadly in agreement with what would be expected, but on analysis was found to be so greatly affected by the attachment of the laterals to alternate floorbeams as to make any numerical comparison impossible. The stresses in the laterals caused by vertical loading were found in agreement with the amount computed from the bottom-chord elongation, in that part of the influence lines (fig. 3) which is of normal form; the increased lateral stresses in the loaded panels appear to be attributable to the spreading effect of the floorbeam bottom flange elongation. The greatest percentage of the chord stress carried by the lateral system amounted to 6 1/2 %, but the large percentages occurred in the end panels, where the stresses were small in amount. The percentage of stress that went through the chord itself increased with the amount of the theoretical stress; a maximum of 93.6 %.

Under horizontal loading the measured floorbeam moments were found to be 10 to 20 % less than the calculated, due to the rigidity of the attached members of the floor system.

A few tests made with combined vertical and horizontal loading (but not with loads at the same panel point, as the horizontal straining device interfered with the vertical-load truck) resulted in showing that the measured stresses correspond to the sum of the separate stresses due to vertical and horizontal loading, with slight excess of the measured values under combined loading. This effect is charged to the reduction of restraints that have a relieving effect when only one form of loading is applied.

Maintenance cost statistics worth while,

By Charles WEISS.

Fig. 1, p. 924.

(Railway Maintenance Engineer.)

That individual who originated the conception that statistics are only lies under a different name had a rather warped notion regarding this important subject. It is very true that statistics have been used or abused to prove many untruths, either because they are not applicable to the subject in hand or not sufficiently extensive or because the arguments were based on false premises and used only some insignificant part of the data. This should not, however, detract from the true value of figures. The important points to determine are : 1° how extensive are the figures; 2° do they represent average conditions, and, if not, have peculiar or local conditions been explained and allowed for, and 3° was the data taken by capable and trustworthy parties? The situation is really analogous to the application of most empirical formulae. If used blindly very erroneous results may be obtained, but it is essential to interpret properly all constant and peculiar conditions.

With the above thoughts in view it is desired to show what a valuable by-product and how great an investment for the future of an engineer or supervisor, carefully compiled records are. The engineer is a busy man and has but little time for such additional duties as compiling records. It is nevertheless to his very great advantage to maintain careful records of work done under his direction, and he can get the essential facts without the loss of much time. In fact, it will be seen that much of what is hereafter referred to can be done by some subordinate clerk or rodman. After a proper start and with occasional criticism or correction, such work will run on almost automatically. At the outset, the following requirements should be fulfilled : simplicity of compilation, ease of representation and, more important still, ease of understanding.

Very few maintenance men pay much attention to this subject as may be surmised from the different estimates two men will often give for the same piece of work. They may both be capable technical men, but, having kept no records, they can only guess at probabilities. Intelligent planning of work and the preparation of budgets, estimates and seasonal or annual programs is very dependent upon the accumulation of figures from work that has been done in the past. To compute the force required on a division during a year, it is not only necessary to know what material will be needed, but also what the capacity of one man is in applying different classes of this material. We must know how many ties one man can install in an eight-hour day, how many yards of ballast he can clean and similar information. In figuring the cost of a proposed piece of new work it is necessary to know the cost of such items as laying a ton or foot of new rail, installing switches, unloading ties, etc. Average conditions should, of course, be aimed at.

These same data are the most reliable basis for determining how long it will take to complete the same piece of work.

Unless a contractor has such knowledge he will be sadly underbid by another who has, or he will be entering the contract financially blind. The more such data he has the closer margin he can cut, and the more economical results will be assured for all parties concerned. Since 1914 prices and man power have been such uncertain, volatile quantities and have been changing so rapidly that the accumulation of data have been of very slight practical value. Past performance was indeed a poor criterion for future guidance. Furthermore, cost was of secondary importance to the matter of getting the job done. Money was plentiful, but men were scarce. These unusual conditions have now largely disappeared and we have already reached a degree of stability that, warrants the practice of rigid economy, one vital feature of which calls for accurate records. Prices of materials and wage scales will undoubtedly undergo further readjustment, but the performance of labor has in many instances already reached pre-war standards. No arguments need be presented here to prove that competition in the future will be much keener than it has been for a long time. Axiomatic as that statement is, it further emphasizes the importance of being able to compute our requirements closely.

The budget question, like all others, possesses many peculiarities. Maintenance men often complain about the arbitrary manner in which their allowances are slashed and determined by the management. Such practice is indeed very common and fundamentally wrong. It is unscientific and causes serious disruptions of well-laid plans. But it is not entirely one sided. Maintenance men overlook or ignore the fact that their own estimates are very often merely guesses. They have kept such meager data that their figures are based upon more or less vague recollections of offhand observations. Higher officers, often from their own early experiences, know this to be the case, and can therefore hardly be blamed for not placing implicit confidence in the estimates they receive, preferring rather to be guided by their own judgment as influenced by larger questions unknown to subordinates.

Critics will argue that budgets and records such as are referred to herein represent a waste of time. Their strong point is that only a certain number of men will be allowed, and that merely keeping a record of where the money goes to will not hold any of it back. After the vast amount of discussion that has recently filled the newspaper and magazine columns on the subject of the national budget, it seems useless to discuss the subject with such unwary ones. If they are unaware of the economies that have been effected in state and municipal governments after the introduction of budgets, a little study of the subject might prove very illuminating to them. A talk with any housewife who keeps a record of her household expenses will also prove convincing, for the identical principle is involved in all the instances cited. The housewife will tell him that before keeping records she did not realize where the money went to, but after doing so she was startled at the enormity of some supposedly insignificant items. A slight study of them showed her where she could effect considerable savings. This situation is analogous to an entire railroad system as well as to an individual foreman's section of the same. One method of eliminating waste, the greatest handicap to our industrial efficiency, is to keep records and study them.

In railroad as well as in most other kinds of work, such information presents an excellent basis for comparing work done in different localities and with different men, methods, tools, etc. Allowing for unusual conditions, it is an ac-

curate yardstick with which to measure efficiency of single individuals, gangs and foremen or of even larger units. Quality of performance must not be overlooked in this study of quantity, for it is just as important. Extensive records make it possible to locate the laggards and either to spur them on to greater effort or to remove them from the organization. They also indicate where the best and also the poorest methods are probably being used, further study of which may reveal valuable information. They show us where the machine should be lubricated and friction eliminated.

The offhand objection to this question of records is that it involves too much bookkeeping. There is undoubtedly the possibility of going into too much detail, but the fundamental facts can be ascertained without much detailed labor, as previously stated, principally with the aid of some low-paid subordinate.

On practically all railroads, as well as on engineering projects in general, the foreman or a timekeeper, shows either in a time book or on time sheets all the information that is the basis for maintenance or construction costkeeping. This record must show the number of men working and the hours made by each with corresponding totals, in order that payrolls may be prepared properly. In addition, notation is usually made of what was accomplished, as, for example, raising 16 rail lengths of track, 4 inches, 88 h.; leveling ballast, 24 h.; total, 112 h. On separate forms the foreman also accounts for material used and reclaimed or salvaged. A brief account like the above takes very little effort on the part of the foreman and is very essential for efficient progress, for it makes him realize that his work can then be watched accurately and compared with that of other gangs. Unless he supplies this information he has very little incentive for getting the utmost work out of his men, and will probably try to get by with the minimum of effort. Assuming, therefore, that the time sheets or books furnish a quantitative description of what was done for the time worked, it only remains to combine the figures. Up to this point not one minute's extra labor has been required, and the remainder is a simple clerical matter, which also involves but very little time or expense. Usually a clerk or timekeeper or a rodman is available who rarely has enough work to keep him busy. However, even if such a man is not available, the data compiled will be referred to so often for other reports that the time saved there will compensate for the extra expense involved in working up the figures.

A card index or loose-leaf system is about the simplest. Taking the matter up in detail : each gang will have a similar set of cards for it, each card being devoted to one of the most common operations. Thus foreman John Jones has a card for installing ties, one for raising track, one for leveling ballast, etc. It may be arranged as indicated :

Section 9. Foreman, John Jones, Middletown.

DATE.	Hours labor.	Number installed.	Remarks : Main track.	Total cost.	Ties.	
					Cost per tie.	Number per man.
4-6-21	80	96	...	$ 32 00	33c	9.6

At some regular period, as at the end of the month, all the figures on the page are totalled and averaged. They can then be transferred to a similar page in a more permanent book, which is devoted to the same item for the entire division, excepting that in this particular case, one page would be devoted to main track, one to siding and another to yard ties. There each foreman's efficiency can be noted at a glance, and the final average for the year will give a very reliable figure to use for future estimates. For items that do not appear very often, as for installing switches, separate cards are not required for each foreman, but a single page is used for it in the book. A column should be included, however, wherein the foreman's name can be entered. The actual daily routine should be somewhat as follows : the time sheets are first assembled in the order that they appear on the payrolls, which is the same order used for the cards. The sheets are then taken in rotation and the amounts transferred to the corresponding cards. The total operation for a force of several hundred men should not take more than 15 m. daily, as the mathematical calculations can be made with a slide rule.

The following items, at least, shoud be kept track of and as many more as desired :

Cost of laying rail per ton or per foot for various weights of rail in main and other tracks.

Cost of installing ties in main and other tracks.

Cost of raising one foot of track various heights in different kinds of ballast.

Cost of cleaning track per foot or yard.

Cost of installing switches, cross-overs and crossings of various kinds.

Cost of applying tie plates, rail anchors, braces, clamps, splices, bolts, etc.

Cost of leveling various kinds of ballast.

Cost of loading and unloading ties, ballast and other material.

Cost of gaging, lining and spot-surfacing track per foot.

Cost of tamping ties.

Cost of tightening and oiling bolts, per mile, per year.

Cost of policing tracks and right of way per mile per year.

Cost of various incidental items, such as masonry work, repairing crossings, etc.

Cost of work train service, per hour and for various kinds of work.

Extensive tests of various devices and methods are in constant progress on most railroads to determine their economy or efficiency. Very often, however, there is no substantial basis for comparison with other similar materials or means. Furthermore, we are rarely in a position to give comparative figures accurately, and when we realize how necessary such information is for future progress and guidance, the value of collecting data similar to that suggested by the following, will also be very apparent:

Relative cost of maintaining track in cinder, stone, slag and gravel ballast.

Relative cost of maintaining freight and passenger tracks.

Relative cost of maintaining tracks on straight lines and curves.

Relative cost of tamping ties by hand and with automatic tampers.

Relative cost of cleaning ballast by hand and by machine.

Relative cost of ditching by hand, steam shovel, narrow gage cars, etc.

Relative cost of maintaining earth, masonry and sodded slopes and ditches.

Relative cost of maintaining and erecting wire, wooden and concrete right of way fences, snow and inter-track fences.

Relative cost of maintaining track with wood and steel ties.

Relative cost of maintaining various types of poles, lamp-posts, crossings, signals, culverts, pipes, switch stands and lamps, etc.

Relative cost of applying various types of splices, rail anchors, tie-plates and other fastenings, as well as cost of maintaining same.

Relative cost of unloading rail, ballast and other materials by different means.

Relative cost of laying rail by different methods or practices.

The salient features of comparative cost data can be simply shown graphically by plotting figures for each unit at regular periods, either monthly or annually. Such charts similar to that shown for ties can be made for the principal items and of pocket-note book size. A few of these tell the entire story at a glance, and in a manner that can be very much appreciated by higher officers. Similar charts can be worked up to show what is being accomplished quantitatively, that is, the number of ties installed, the amount of track raised, and so on.

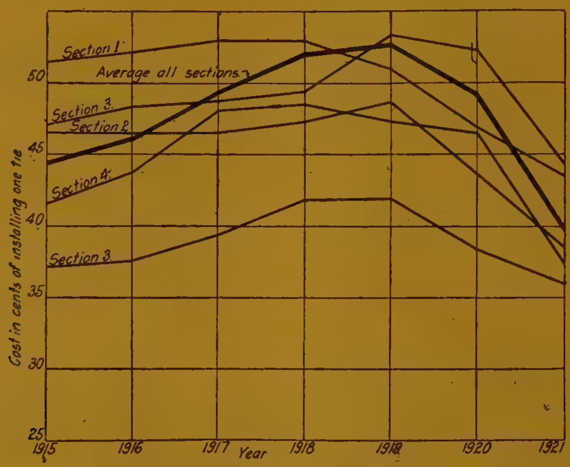


Fig. 1. — The cost of installing ties on sections.

The mass of information referred to here can be obtained with very little expenditure of time. It shows not only actual costs and comparative costs, but indicates the capacity of men in different lines of work. By training the foremen, still other equally useful information is secured, such as the average life of ties, rail, ballast and other material, the frequency with which ballast should be cleaned, and above all, the annual requirements. The latter very important consideration is at present usually a guess, based upon previous guesses. These guesses often require as much labor as getting the facts, and they would all be eliminated with the introduction of some such simple system as the one outlined above.

MISCELLANEOUS INFORMATION

[385. (09.2]

1. — Retirement of Mr. Robert Winkler, technical director of the Swiss Federal Postal and Railway Department, member of the Permanent Commission of the International Railway Association.

The following is the text of the official letter by means of which the Federal Railway Department informed the Swiss presse of the resignation of our eminent and sympathetic colleague, Mr. Robert Winkler :

Mr. Robert Winkler, Engineer, has just resigned, on account of ill health, his post of Director of the Technical Service of the Swiss Federal Railway Department, after having held the same with great distinction for 21 years. The thanks which the Federal Council have offered him for the services which he has rendered to the nation are by no means a mere formality.

It was in 1901 that Mr. Winkler, who was then Director of the Pilatus Railway, was appointed to this position by the Federal Councillor Mr. Zemp, who anticipated that it would be very necessary to have a competent technical collaborator, in view of the important developments, from the constructional point of view, which were about to take place in the nationalised railways. Mr. Winkler has certainly fulfilled the great hopes which were then placed in him. In this important post and throughout his long career he has not only acquired the esteem and confidence of the railway administrations in his own country, but has also excercised an influence which has often been the decisive factor in solving international railway problems.

At the present time, the regret of having been obliged, by reasons of health, to abandon the duties in which he took such an interest, is increased by the thought that some of the progress which he has helped to effect, as regards railway unification on the continent, appears to be threatened by the after effects of the world war.

We hope that our distinguished friend may long enjoy the rest which he has so well earned.

We join with the Federal Department in wishing our esteemed colleague a rapid return to health.

The Executive Committee.

[656 .284]

2. — Dynamiting sub-strata overcomes slides.

By C. M. McVAY,

DIVISION ENGINEER, NEW YORK CENTRAL LINES, CHARLESTON, W. VA.

Figs. 1 and 2, pp. 926 and 927.

(*Railway Maintenance Engineer.*)

During the building of the Kanawha & West Virginia's new line from Gauley Bridge to Belva, W. Va., between September 1917, and June 1919, a bad slip occurred at Belva, the handling and relief of which gave rise to very interesting problems. The slip extended a dist-

ance of 900 feet along the new line. The maximum depth of cut on the center line at this point of the slide was about 30 feet and the preliminary sections called for 22 559 cubic

Fig. 1. — Clearing up another slide.

yards of excavation. When construction work was completed, however, a total of 75 361 cubic yards had been removed and since that time about 800 yards additional have been taken out by a ditcher.

C. W. Marshall, a contractor of Kansas City, Mo., started work in this cut in the latter part of September 1917. The weather was very dry at that time and by November the cut had been made and the work was thought to be completed. About the middle of December, however, wet weather set in and after two days it was impossible to tell that a shovel had ever been in the cut. A county road ran along the lower side of the cut and as the cut filled in the earth not only completely covered the new railroad grade, but the county road as well, the grade being buried to a depth of about 18 to 20 feet on the center line. The county road was made passable at once by team work, but as the contractor's equipment had all been moved down the river to the next cut, further work in the cut was postponed until spring.

About the middle of May, therefore, after the earth had thawed out and dried thoroughly, the excavation of the slide was begun and it was all but completed when a recurrence of rainy weather brought on another slide, making it necessary to remove the shovel for a few days. As soon as the weather cleared up another cut was then made through the slip. This cut stood in good shape for several weeks, as a result of which the standard track was laid at this point, but in September 1918, during a wet spell, another slip occurred and the track was entirely covered. The shovel cleared this earth away by casting it over to the side adjacent to the county road, from which location the material was then loaded into cars on the main track. Immediately after this was done a temporary track was constructed along the side of the county road to be used as a loading track in case of another slide. This was a double end track, which provided the means of getting around the slide unless it came down to a greater extent than anticipated. In January 1919, therefore, when another slide covered the main track and part of the loading track, this temporary track was utilized for passing trains, while the slide was cleared from the main track.

It was evident that the ordinary remedies

for slides, such as piling, bulkheads or walls, would not hold or stop this movement, as it all came from above and would have covered such structures in a short time. The top of a hard layer of blue clay, soapy and impervious to water, extended 6 to 10 feet above the new grade. The entire formation above the blue clay was a sandy yellow clay with about 30 % of boulders and loose rock. This formation was very porous and the water ran down through it to the blue clay formation and then along the top of this to the face of the cut. The top formation was loosened in this manner and in wet weather simply slipped over the blue clay.

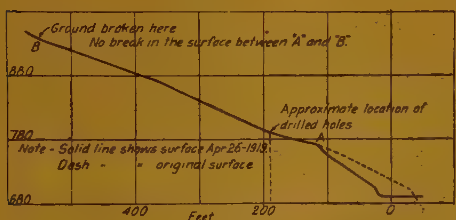


Fig. 2. — An average section through the hillside.

In May 1919, a break was discovered about 500 feet up the side of the mountain and the entire section below it seemed to be moving towards the track. It was then determined to attempt a remedy by drilling through these upper formations to the solid rock and breaking up the various strata by explosives so that the water would pass through them rather than flow toward the face of the cut. A four-inch « Cyclone » gasoline drill was installed and holes drilled about 75 feet back of the top of the slope of cut and 75 feet apart. A total of 11 holes were drilled, ranging from 95 feet to about 130 feet deep. These holes were from 110 to 190 feet from the center line of the main track. They were drilled from 8 to 10 feet into the soapstone formation which surmounted the solid rock 20 to 25 feet below grade. It was necessary to case the top part of each hole in the sandy clay and boulders. As soon as a hole was drilled it was sprung and immediately loaded and shot. About 100 lb. of dynamite was placed in the bottom or rock shot and about 75 lb. in the upper or blue clay shot, the latter being placed at about the height of the grade. Between the lower and upper shots the holes were filled with sand. The holes necessitated their shooting quickly after cleaning as water ran in very rapidly. In each case the casing was pulled after the hole was loaded and everything made ready for shooting.

There was no distortion of the face of the cut or the ground around the hole as a result of the shooting and the surface dried up immediately. Since the completion of these holes two years ago the cut has held up in good shape and has never blocked the track. As the front slope is now becoming well covered with vegetation no further trouble of a serious nature is anticipated. The total length of holes drilled was about 1 232 linear feet. The total cost of drilling and shooting the holes was $1 816.92, which represents a cost of approximately $1.47 per linear feet of hole. The entire work of drilling and blasting was started late in May 1919, and finished early in July.

[**621. 132 .4** (.73) & **621. 132.5.** (73)]

3 — New locomotives for the Northern Pacific.

Fig. 3, p. 929.

(*Railway Age*).

The Northern Pacific placed one of the largest orders for locomotives given in 1920. This consisted of 20 eight-wheel switchers (0-8-0 type), 20 Pacific (4-6-2 type), 25 Mikado (2-8-2 type) and 6 Mallets (2-8-8-2 type), all of which were built by the American Locomotive Company at the Brooks plant.

Pacific type.

The Pacific type locomotives, railroad Class

Q-5, are of a new design developed to meet the need for a heavier fast passenger engine to haul the overload trains. They have been assigned to all divisions between Dilworth, Minn., and Missoula, Mont. The profile on these divisions varies from comparatively level to grades of 2.3 %, which occur in the Rocky Mountains, with curves up to 16 degrees. The average train consists of 12 cars, although in the summer season the number occasionally reaches as high as 17. The majority of these locomotives operate over two divisions or subdivisions of about 110 miles each, crews being changed at the end of each sub-division. In other cases the locomotives are assigned to the heaviest runs in such a way that they double the subdivision each day, there being in such cases either two crews assigned to each engine or three crews to two engines.

These Pacific type locomotives have a rated tractive effort of 41 900 lb. with 26 by 28 inch cylinders, and 73 inch driving wheels and weigh 314 000 lb., of which 181 000 lb. is on the drivers. They have boilers of the conical connection type with wide firebox, combustion chamber 39 inches long, tubes 18 feet long, brick arch and superheater. The tenders are equipped with coal pushers.

Mikado type.

The Mikado type locomotives, railroad Class W-3, are similar in design to previous locomotives which have been found to be well suited to general traffic conditions on the Northern Pacific. They are used in main line freight service on several divisions having profiles of different characteristics. On the Pasco division they run 153 miles, 90 miles of which is a 0.4 % continuous grade, and handle trains of 3 200 tons. The Yellowstone division profile between Mandan, N. D., and Glendive, Mont., is a series of ascending and descending grades, with ruling grades of 1.2 % both eastward and westward. The rating on this division is 1 775 tons in both directions. On the Seattle division between Auburn and Lester, Wash., a fairly uniform 1.0 % grade occurs, and the tonnage rating for this portion of the division is 1 600 tons. From Lester to the summit helpers are used and they are also employed on several other divisions in the mountainous sections.

These Mikado type locomotives have a rated tractive effort of 57 100 lb.; 28 by 30 inch cylinders and 63 inch driving wheels, and weigh 337 000 lb., of which 247 000 lb. is on the drivers. The boilers are of the conical connection type, provided with brick arches, combustion chambers 36 inches long, tubes 18 feet long and superheaters.

Mallet type.

The Mallet type locomotives, railroad Class Z-3, are similar to previous 2-8-8-2 locomotives used on the Northern Pacific. They are employed as helpers in freight service on the Rocky Mountain and Montana divisions where grades are heavy. On the Seattle division they are used as road engines, handling 2 400 tons between Auburn and Lester, the grade being uniformly 1.0 %. Helpers are used from Lester to the summit of the Cascade Mountains.

These locomotives have a rated tractive effort of 105 100 lb. operated simple and 87 600 lb. operated compound. They have a total weight of 483 000 lb. exclusive of the tender, of which 419 500 lb. is on the drivers. The high pressure cylinders are 26 by 30 inches the low pressure cylinders 40 by 30 inches, and the driving wheels are 57 inches in diameter. The boilers are of the conical connection type, firebox 126 1/8 by 96 1/4 inches, with combustion chamber 56 inches long, tubes 24 feet long, brick arches and superheaters.

Eight-wheel switchers.

These locomotives are of a new design and resemble closely those ordered by the U. S. R. A. Both designs are of the same rated tractive effort, have the same size cylinders, driving wheels and wheel base and the boilers are similar. They have 25 by 28 inch cylinders, 51 inch wheels, weigh 217 000 lb., a wheel base of 15 feet and are designed to operate on 19° curves.

Details and specialties.

Longitudinal boiler seams are welded for a length of 18 inches at front and back except

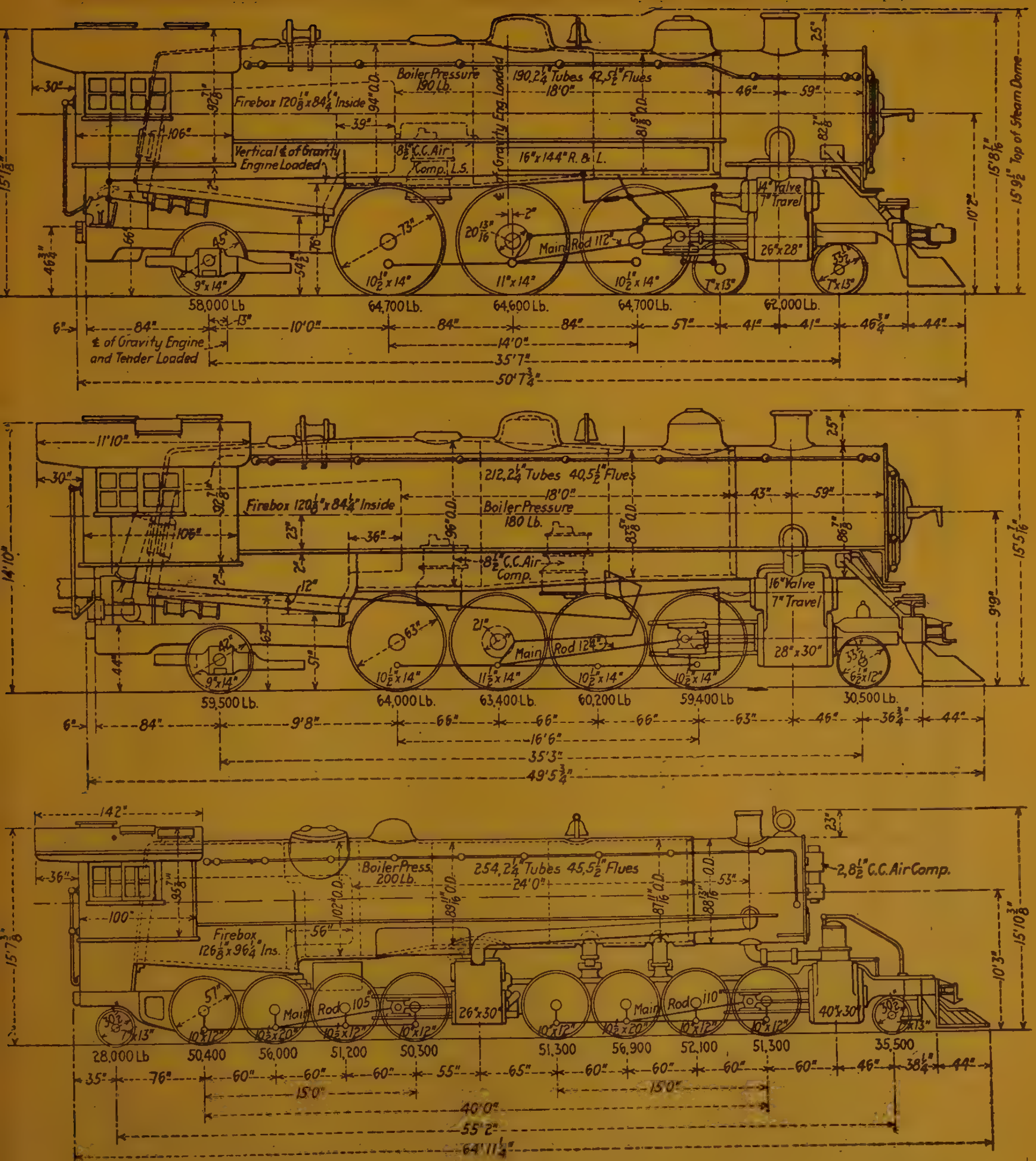


Fig. 3. — Side elevations of Pacific, Mikado and Mallet types for the Northern Pacific.

Dimensions, weights and ratios of New Northern Pacific locomotives.

	Switch 0-8-0.	*Pacific* 4-6-2.	*Mikado* 2-8-2.	*Mallet* 2-8-8-2.
Tractive effort, 85 °/₀, m. e. p.	51 000 lb.	41 900 lb.	57 100 lb.	105 100 simple. 87 600 compound.
Speed at estimated maximum horsepower.	...	46.5 m. p. h.	11.8 m. p. h.	10.6 m. p. h.
Cylinders, diameter and stroke	25 by 28 inches.	26 by 28 inches.	28 by 30 inches.	H. P., 26 by 30 inches. L. P., 40 by 30 inches.
Valves, kind and size	Piston, 14 inches.	Piston, 14 inches.	Piston, 16 inches.	H. P., piston 14 inches. L. P., slide.
Greatest travel	6 1/2 inches.	7 inches.	7 inches.	H. P., 6 inches. L. P., 6 inches.
Lap	1 1/16 inches.	1 1/4 inches.	1 3/16 inches.	H. P., 15/16 inch. L. P., 13/16 inch.
Exhaust clearance	0	1/4 inch.	0	H. P., 1/4 inch. L. P., 7/16 inch.
Lead in full gear	1/16 inch.	F, 1/16 inch. B, 9/16 inch.	1/8 inch.	H. P., 1/4 inch. L. P., 3/16 inch.
Weights in working order :				
On drivers	217 000 lb.	181 000 lb.	247 000 lb.	419 500 lb.
On front truck	...	69 000 lb.	30 500 lb.	35 500 lb.
On trailing truck	...	64 000 lb.	59 500 lb.	28 000 lb.
Total engine	217 000 lb.	314 000 lb.	337 000 lb.	483 000 lb.
Tender	163 000 lb.	198 600 lb.	214 000 lb.	213 000 lb.
Total engine and tender	380 000 lb.	512 600 lb.	551 000 lb.	696 000 lb.
Wheel base :				
Driving	15 ft. 0 in	14 ft. 0 in.	16 ft. 6 in.	15 ft. 0 in., and 15 ft. 0 in.
Total engine	15 ft. 0 in.	35 ft. 7 in.	35 ft. 3 in.	55 ft. 2 in.
Total engine and tender	53 ft. 1/2 in.	71 ft. 3 1/4 in.	70 ft. 11 1/4 in.	83 ft. 6 1/4 in.
Wheels and journals :				
Driving wheels, diameter over tires	51 inches.	73 inches.	63 inches.	57 inches.
Driving journals, diameter and length :				
Main	10 by 12 inches.	11 by 14 inches.	11 1/2 by 14 inches.	10 1/2 by 20 inches.
Others	9 by 12 inches.	10 1/2 by 14 inches.	10 1/2 by 14 inches.	10 by 12 inches.
Front, truck wheels	..	33 1/2 inches.	33 1/2 inches	30 1/2 inches.
Trailing truck wheels	...	45 inches.	42 inches.	30 1/2 inches.
Tender wheels	33 inches.	36 inches.	36 inches.	36 inches.

Dimensions, weights and ratios of New Northern Pacific locomotives *(continued)*.

	Switch 0-8-0.	*Pacific* 4-6-2.	*Mikado* 2-8-2.	*Mallet* 2-8-8-2.
Boiler, type.	Straigth top.	Conical Conn.	Conical Conn.	Conical Conn.
Steam pressure	175 lb.	190 lb.	180 lb.	200 lb.
Fuel	Bit. coal.	Sub. Bit. coal.	Sub. Bit. coal.	Sub. Bit. coal.
Diameter, first ring, inside	78 9/16 inches.	80 inches	82 inches.	86 inches.
Firebox, length and width	102 by 66 1/4 inches.	120 1/8 by 84 1/4 inches.	120 1/8 by 84 1/4 inches.	126 1/8 by 96 1/4 inches.
Combustion chamber, length	...	39 inches.	36 inches.	56 inches.
Arch tubes, number and diameter	3 — 3 inches.	4 — 3 1/2 inches.	4 — 3 1/2 inches.	4 —
Tubes, number and diameter	229 — 2 inches.	190 — 2 1/4 inches.	212 — 2 1/4 inches.	254 — 2 1/4 inches.
Flues, number and diameter	36 — 5 1/2 inches.	42 — 5 1/2 inches.	40 — 5 1/2 inches.	45 — 5 1/2 inches.
Tubes and flues, length	15 feet.	18 feet.	18 feet.	24 feet.
Heating surface, firebox	185 square feet.	300 square feet.	288 square feet.	332 square feet.
Heating surface, arch tubes	18 —	35 —	35 —	41.6 —
Heating surface, tubes	1 785 —	2 002 —	2 234 —	3 575 —
Heating surface, flues	772 —	1 082 —	1 030 —	1 548 —
Heating surface, total	2 760 —	3 419 —	3 587 —	5 497 —
Superheater surface	652 —	928 —	874 —	1 305 —
Equivalent heating surface	3 738 —	4 811 —	4 898 —	7 454 —
Grate area	47 —	70.3 —	70.3 —	84.3 —
Tender :				
Water capacity	8 000 gallons.	10 000 gallons.	10 000 gallons.	10 000 gallons.
Fuel capacity	12 tons.	14 tons.	16 tons.	16 tons.
Ratios :				
Weight on drivers ÷ tractive effort	4.25	4.32	4.32	Simple : 3.99 Compound : 4 78
Tractive effort × diameter drivers ÷ equivalent heating surface	696	636	735	Simple : 804 Compound : 670
Equivalent heating surface ÷ grate area	79.5	68.4	69.7	88.4
Firebox heating surface ÷ equivalent heating surface, %	5.43	6.98	6.59	5.01
Total weight ÷ equivalent heating surface	58.1	65.2	68.7	64.8

the seams over the combustion chamber which are welded at the front end only on the Pacific and Mikado locomotives and are not welded on the Mallets. The top seam in the smoke box is also welded. The fireboxes of all types have the crown and side sheets made of a single piece. The combustion chamber is also made in one piece, butt welded on the bottom center line and butt welded to the firebox crown. Two 2 inches combustion tubes are used in each side of all fireboxes. Injectors are of the Hancock non-lifting type and feed water enters the boiler through vertical check valves. All boilers are equipped with Butterfly firedoors and brick arches. Duplex type D stokers are used on the Mikado and Mallet locomotives, and coal pushers on the tenders of the switcher and Pacific locomotives.

Driving axles are of hammered open-hearth steel, oil heat treated. Front truck, trailing truck and tender axles are of open-hearth carbon steel, oil heat treated, as are also the crank pins. On the Mallet engines the main crank pins are hollow bored. Bushings in cylinders and steam chests and also packing rings for main and valve pistons are of Hunt-Spiller iron. Extended piston rods are used on the Mikado locomotives and on the low pressure cylinders of the Mallets. Walschaerts valve gear is used on all types. Ragonnet power reverse gear is applied to the switch engines, while the locomotives of the other types have Mellin reverse gears with oil pistons. Other specialties used are Pyle National electric head and back-up lights, Franklin grate shakers, pneumatic cylinder cocks and Chicago flange lubricators.

The important dimensions, weights and factors of the four types of locomotives are given in tabular form herewith.

[621 .33 (.42)]

4. — Electrification of the British railways.

In March 1920, the British Minister of Transport appointed an Advisory Committee to study a certain number of problems arising from the electrification of railways, the Terms of Reference under which it was appointed being as follows :

« I. — Whether any regulations should be made for the purpose of ensuring that the future electrification of railways in this country is carried out to the best advantage in regard to interchange of electric locomotives and rolling stock, uniformity of equipment and/or other matters.

« II. — If any such regulations are desirable, what matters should be dealt with, and what regulations should be made.

« III. — How far it is desirable, if at all, that railways or sections of railways already electrified should be altered so that they may form parts of a unified system. »

Subsequently in October 1920, two further questions were referred to the Advisory Committee :

« I. — Whether any regulations should be made to limit the drop of potential in an uninsulated return conductor on electrically operated railways.

« II. — If any such regulations are desirable, what limits these should impose, and under what conditions. »

The reply to the first three questions having been duly published, it does not appear necessary to return to this subject, but for the sake of convenience, we will simply repeat that the Committee consider it desirable that certain general regulations should be made for observance by the railway companies when electrifying their lines, and directed specially to ensuring standardisation of those methods and appliances which are likely to prove most satisfactory under British conditions. These regulations should be pliable enough so as to put no avoidable difficulties in the way of the adoption in future of any improvements which may from time to time become available with increasing knowledge and experience. On the other hand, the Committee considered that for feeding the lines, the direct current system at a pressure of 1 500 volts or of a multiple or

sub-multiple of this number, according to the nature of the case, should be used, and that the current generated for direct current lines should be alternating three phase at 25-50 cycles. Finally, it recommended that the electrification of the London & Brighton Railway should not be interfered with, the only one to which at the present time paragraph III could be applied.

The Advisory Committee have just published a supplementary report, which not only contains the reply to the two last questions asked by the Minister of Transport, but completes the provisional report it had prepared in the Autumn of 1920.

It states at the commencement that the mass of evidence put before the members during their enquiry, as well as their own experience, has only confirmed them more strongly in the view — expressed in their preceding report — that alternating current supply to sub-stations at a frequency of 50 cycles can be used for railway purposes without any detriment to railway working.

Discussing then the distribution of energy along the lines, it insists on the necessity of adopting, in order to ensure the intercirculation of the trains, a type of conductor which can be utilised indifferently by locomotives working normally at different pressures (1 500 and 600-750 volts). In the case of distribution by third rail, the current can be collected in two ways, either from the top face or from the bottom face of the electrified rail. The first method, which is generally used for currents of low voltage, is mostly in use at the present time; the Advisory Committee, however, do not hesitate to give its preference to the second, which has the advantage of making it easier to insulate the rail, thus rendering it safer for the men working on the track, allows the use of higher pressures, and in addition that of being better protected from weather conditions. The latter advantage is no less important than the others, especially in Northern countries when snow and ice, accumulating on the top face of the electrified rail, sometimes cause the contact to be extremely defective. However, whilst favouring the second method, the Committee in no way condemns the first; on the contrary, it considers that both methods may be used concurrently, being possible to fit locomotives without any great difficulty with suitably designed shoes adaptable for either system.

The two last questions asked by the Minister of Transport are answered in the negative, the Committee considering that the accidents due to a rise of potential above that allowed by the present regulations on the return conductors that are uninsulated have been, up till now, too few and too unimportant to necessitate the issuing of special regulations.

In concluding, the Advisory Committee sums up as follows :

Nature of current suggested for the central sub-stations : three phase alternating;

For the distributing lines : direct current system.

Standard pressure : 1 500 volts at the sub-station bus bars; a multiple or sub-multiple of this pressure in certain particular cases subject to the approval of the Minister.

Method of collecting the current : electrified third rail (collecting from either top or bottom faces), or by overhead wire, this being placed over the track in the open 3 feet above the maximum load gauge likely to be used on the line, and 20 feet above rail level at its highest point.

M. Peschaud.

[621 .33 (.52)]

5. — The electrification of the Japanese railways.

The *Board of Trade Journal* (5 January 1922) gives the following information, taken from the *Journal of the Yokohama Chamber of Commerce*, on the electrification scheme which has just been definitely decided upon by the Japanese Minister of Public Works, and

which should apply to 2 000 miles of track :

1° Suburban lines to be electrified to prevent congestion of traffic :

	Miles.
Kyoto-Kobe	47
Minato machi (Via Kitsu) Kyoto	51
Kobe-Himeji	34
Moji-Hakata	48
Osaka-Tennoji	6

2° The following lines are those in mountainous country, with steep gradients and numerous tunnels :

	Miles.
Odawara-Numazu	26
Maibara-Imasho	47
Hachioji-Shiojiri	116
Nagoya-Shinooi	151
Fukushima-Yonazawa	26
Yashiro-Kashima	94
Kameyama-Nara	46
Utsu-nomiya-Nikko	25
Koriyama-Niigata	172
Oguda-Shinjo	58
Takasaki-Yokokana	18
Karuizawa-Naoetsu	92

3° On the following, advantage will be taken of the change in the method of traction to make a number of deviations to the lines, which will thereby be appreciably shortened :

	Miles.
Numagu-Kyoto	244
Himaji-Simonoski	295
Ohmiya-Fukushima	151

4° On all the above lines, as well as on the following, electric energy will be obtained from « white coal » :

	Miles.
Imasho-Naoetsu	181
Nagoya-Kameyama	38
Ohmiya-Takasaki	46

5° Finally, on the following lines, which run through districts where coal is plentiful and cheap, the electric power will be produced from this fuel :

	Miles.
Kokura-Wakamatsu	56
Muroran-Yubari	90

M. Peschaud.

[621 .33 (.83)]

6. — The electrification of the Chilian railways.

The railways of Chili consist at the present day of 5 200 miles of track, of which about 30 % are private lines (principally industrial concerns and mining companies). Distinction must be made between the lines South of Valparaiso which are broad gauge (5 ft. 6 in.) and those which are situated to the North, which are as a rule narrow gauge.

Since the war, the Chilian Government has felt the need for electrifying the State Railways owing to restriction of traffic due to the shortage of coal, and the effect which the considerable rise in price of this fuel has had on the national finances. Thus, a Commission on electrification was appointed in 1918. It completed its task in the course of the year after a careful investigation of the methods of electrification in use in other countries, and has proposed a scheme of considerable magnitude for the electrification of the National Railways.

At the present time, only the electrification of the Valparaiso-Santiago line (116 miles) and the Las-Vegas-Los Andes branch (28 miles) is under consideration. To raise the capital necessary for this enterprise, a loan of $10 500 000 was put upon the Chilian market, and according to the *Railway Age*, was practically subscribed in a few hours.

The second part of the programme will deal with the electrification of the Transandine Railway, a narrow gauge line which connects with the above mentioned at Los Andes, and afterwards with the electrification of the « Longitudinate », another narrow gauge line which leaves the main Valparaiso-Santiago line at Calera and runs due North. All these lines through mountainous country include

many tunnels and heavy works of all types, steep gradients and sharp curves; electric traction must in consequence prove beneficial to the development of the traffic.

Electric energy will be supplied to the Valparaiso-Santiago and Las-Vegas-Los Andes lines by three power stations using natural waterfalls situated at several points on the River Colorado; they will develop, when finished, a total power of 120 000 kw. The current will be transmitted to sub-stations at a pressure of 110 000 volts.

Thirty-nine electric locomotives will be necessary to work the traffic on these two lines: six locomotives for express trains, eleven for local traffic, fifteen for freight trains and seven for shunting. They will have the following characteristics :

CATEGORY.	Weight in tonnes.	Length in feet and inches.	Wheel arrangement:	Number of motors.	Total power in H. P.	Speed in miles per hour.
Express	127	58′ 6″	2-6-0 0-6-2	6	2 250	62 1.2
Local	80	40′ 6″	0-4-0 0-4-0	4	1 500	56
Freight.	113	49′ 10″	0-6-0 0-6-0	6	1 680	40
Shunting	65	40′	0-4-0 0-4-0	4	480	34

M. PESCHAUD.

[385 .15 (.42)]

7. — The termination of State control on the British railways.

At midnight on the 15 August 1921, Government control of the British railways came to an end, and the Railways Act 1921, which was carried by a large majority in the House of Commons, set up a new state of affairs. Before the war, the State had only a very limited control over the companies, but the outbreak of war brought about, as in all the belligerent countries, a change in the situation. The basis of the war-time organization of the railways of the United Kingdom is laid down by an Act of 1871, the « Regulation of the Forces Act », and in virtue of this Act, the War Office at midnight 4/5 August 1914, on behalf of the Government, took possession of the railways of Great Britain. The actual management was carried out by an Executive Committee selected from the General Managers of the railways. On the 1 January 1917 the Irish railways were dealt with in a similar manner and placed under a special Executive Committee. As in France, the railways of the United Kingdom were thus placed at the disposal of the Government, but were not handed over to the direct control of the Secretary of State for War. They were entirely managed by the Executive Committee of General Managers, and although this Committee was nominally under the chairmanship of the President of the Board of Trade (this being the authority responsible for the Government supervision in peace time) the actual chairman was one of the members of the Executive Committee. The real working was left to the companies themselves, it not being considered necessary to appoint Government representatives on the Committee.

The same Act of 1871 determined the financial provisions of the period of Government control. It provided that all the owners of the railways thus taken over should be fully compensated for all loss or damage that they may incur through this Act. It was decided on the 6 August 1914 that the compensation to be paid to the companies should be equal to the difference between the total net takings

of their lines during the period of State control, and the amount of these takings for the corresponding period of 1913. In the original arrangement, however, no provision was made for certain charges which from the point of view of equity should be subject to special compensation. These were provided for in subsequent agreements. The capital expenditure incurred by the companies for works brought into use by the Government during the period of control obviously required additional compensation, and therefore the Government undertook to pay interest at 4 % (1) on all expenditure of this nature, including all purchases of rolling stock made after 31 December 1912. Agreement was also arrived at between the Government and the companies as to any reduction in the stock of stores which the companies had bought at pre-war prices, and which the Government had the advantage of using during the period of control. It was further laid down as to the method of dealing with additional works necessitated by the increase in traffic brought about by the war and with the total capital necessary for the same. It was only fair that the companies, deprived during the war of the management of their business and obliged to limit their traffic in order to comply with military necessities, should receive compensation and be indemnified for the various losses incurred by them, owing to the State control of their systems. In order to deal with this question in detail, a Committee known as the «Colwyn Committee» was appointed in 1920, and after lengthy discussion, it was decided and provided for in the Railways Act 1921 that at the termination of the period of State control, the sum of £60 000 000 should be paid as compensation to the companies.

If the companies have been fairly dealt with in this respect, they have however suffered as regards their financial position, in consequence of the increase in the cost of raw materials, and above all, in the very large increases in wages, unwisely granted by the Government. The companies perceived and at once pointed out that as the balance of receipts and expenses had been upset, they would be compelled to resume the working of their lines at a loss. The Government did not wish to dispute this, as the increase of 50 % in the passenger fares made in 1917 was adopted to restrict the traffic rather than to increase receipts. It was pointed out that the increases made in 1917 and 1920 (75 % for passengers and 112 % for goods over pre-war charges), had been postponed too long. The situation became so serious that the working expenses for the railways of the United Kingdom had risen from £78 000 000 in 1913 to £241 000 000 in 1920, while the takings only rose from £124 000 000 to £245 000 000. The State was of course obliged to make up the difference so that the pre-war net receipts could be paid. The amount the State had to find for year 1920 amounted to £46 000 000, and the amount paid up to decontrol on 15 August 1921 was 1 milliard francs. The chief cause of this financial trouble is the increase in wages. The Government improved the conditions of employment, and increased the wages far beyond the limits recommended by the Committee of General Managers, although to a considerably less degree than was done in France. They also introduced the 8 hours day. These measures brought about an increase of 76 000 in the number of employees, which in itself increased the wages bill by 25 %. The total wages bill rose from 47 million pounds sterling in 1913 to £160 000 000 in 1920. In January 1921 the total wages bill further increased to £173 000 000.

The war being over, the necessity for a change was obvious. As a first step towards this, the Government on the 27 February 1919 decided to create a Ministry of Transport, the first Minister being Sir Eric Geddes. This was the first step towards unification; the Minister was to control all transport, have complete authority, and become a sort of State Manager of the railways. The establishment of the Ministry entailed the abolition of the General Manager's Committee. It was first suggested that there should be a Railway Advisory Committee consisting of representatives of the companies and representatives of the employees, but this met with such a storm

(1) This was increased to 5 % from the 1 May 1919.

of opposition that the suggestion was abandoned. A considerable amount of negotiation took place and the Trades Unions abandoned any claim for direct representation on the management. Finally, general proposals, agreed to between the Minister, Sir Eric Geddes, and the railway companies, were embodied in a Bill which passed — after considerable discussion — the House of Commons on the 11 August 1921 and became law before decontrol on the 15 August. Broadly speaking, this new Act is similar to that passed in France, both being based on the same principles, namely, simplification, unification and co-ordination. With the exception of the London suburban railways the whole of the companies in Great Britain are to be grouped into four large systems. Rates and traffic conditions are to be revised and unified. These are to be modified so that a net revenue practically equal to that earned in 1913 may be obtained. The staff, whilst not having a voice in the management is to be consulted as regards conditions of service and rates of pay, whilst wages questions may be referred to two permanent boards. The constitution of these will be dealt with in a later article. This Act, according to the statement of the General Manager of one of the large companies, who is also Chairman of the Executive Committee (Sir Herbert Walker of the South Western Railway) is going to save the railway situation. The £60 000 000 compensation, which the Act guarantees, will enable the permanent way rolling stock, etc., to be put into good condition again; a decrease in wages has already commenced according to a sliding scale system, and the same General Manager estimates that the companies should recover, by 1922, their net profit as in 1913, together with permanent stability.

H. F.

[385 .15 (.42)]

8. — The new position of British railways in consequence of the Act of 19 August 1921.

Government control of the British railways, which was instituted at the commencement of the war, ceased on the 15 August last, when the lines were handed back to the companies. Before this time, several schemes were under consideration for the working of the lines after that date, the Government drawing up a complete one and the Railway Companies Association putting forward one involving a considerable modification of the system of grouping suggested by the Government scheme. In addition to these, the various other bodies, including the Association of British Chambers of Commerce, the traders, the railway shareholders associations and the Railwaymen's Unions gave their opinions on these schemes and made suggestions. The Government scheme was amended and laid before the House of Commons on the 12 May last, and after a prolonged discussion in which various details were altered, it passed the third reading in this House by 237 votes to 82. It subsequently passed the House of Lords and became law on the 19 August 1921.

The Bill differs on certain points to the original scheme put forward in June 1920. This original scheme made provision for the following :

1° A system of amalgamation or fusion of the railways by which the 250 British companies were placed into groups, the larger lines absorbing the less important independent ones;

2° The employees to have a share in the management, having representatives on the Boards of the groups;

3° The sanction of a scale of rates, which in the opinion of competent authorities would, by efficient working, enable the groups to realize a net revenue equal to that of the companies before the war. Any excess profits over this was to form a reserve fund from which the State was to benefit;

4° The permanent establishment of a *Central Wages Board* and a *National Wages Board.*

The Bill, as passed, may be split up into three chief sections :

1° The scheme of amalgamation is retained, but excluding the London suburban companies, the number of groups was reduced to four. Each group consists of from 4 to 8 « Constituent » Companies and will absorb the smaller « Subsidiary » Companies. The groups of « Constituent » Companies are to submit to the Minister of Transport a scheme for amalgamation and absorption before the 1 January 1923, and to come into operation on the 1 July 1923. Failing agreement, the matter is to be settled by the amalgamation tribunal set up under the Act. Certain Joint lines owned by « Constituent » Companies not in the same group, are not included in the scheme;

2° The suggestion of the representatives of the employees on the Boards of the groups was abandoned. The *Central Wages Board* and *National Wages Board* mentioned above have been set up. The former of these consists of eight representatives of the companies and eight of the railway employees. The latter has an independent chairman nominated by the Minister of Labour and consists of six representatives of the railway companies, six of the railway employees, and four of the users of the railways. The constitution and functions of the Boards may be defined from time to time by a special committee of six representatives of the General Managers' Committee of the Railway Clearing House and six representatives of the railway unions;

3° The idea of the Government taking any part of any profit in excess of the revenue to pay the same dividend as in 1913 was abandoned. In place of this, any excess over the net revenue for 1913 and 5 % on capital incurred during the period of Government control is to be divided as 20 % to the companies and 80 % to the public in the form of cheaper rates. The rates themselves are to be fixed to give the net revenue obtained in 1913. They and certain other conditions of transport are to be settled by a Railway Rates Tribunal. This is to consist of three persons, one of whom must be « a person of « experience in commercial affairs one a person of experience in railway business » and the third who is President, an experienced lawyer. This tribunal will be assisted by members of two panels. The « general » panel consists of representatives of the traders, labour, and railway passengers, whilst the « railway » panel is formed of railway officials. The Bill confirms the agreement made for the Government to pay to the railway companies £60 000 000 in order that the lines, rolling stock, etc., may be restored to a satisfactory state of repair. Half of this was paid on the 31 December 1921, and the remainder is to be paid on the 31 December 1922.

These are the outstanding features of the Bill which inaugurates a new regime on the British railways. In many respects it is very similar to the measure passed by the French Senate.

It may be summed up briefly as :

1° Establishing four great railway systems;

2° In effecting by the group system a unification of working conditions;

3° Granting rates which should give a net revenue equal to that of 1913;

4° Unifying the rates through a Railway Rates Tribunal;

5° Standardising railway wages, etc., through two Wages Boards on which the employees have representatives.

Thus we have, simplification, standardisation, and by means of the reserve fund, financial solidarity, the three principles on which the French scheme is based, and which we find in the English Act of Parliament. The similarity between the two is a clear indication of the importance which is attached to these principles by two of the largest railway undertakings in Europe.

The two schemes are, however, different in several details. The fixing of rates is, in the English scheme, entrusted to a tribunal, while in the French system, it is done by the Government.

The system of dealing with rates and revenue seems more advantageous than that

granted in France, taking the premium into account.

In the English scheme, the companies receive a substantial sum for the repair of their lines, which appears to be considerably more than the State assistance given to the French companies.

It should be remembered that the 1913 net receipts have been made up to the companies since 1914, while in France the revenue of two companies has been considerably reduced.

The standardisation of working conditions is assured in a more complete manner in the French scheme than it is in the British.

H. F.

[385. (09.2]

OBITUARY

Otto SAND,

Vice-President of the General Direction of the Swiss Federal Railways;
Member of the local Swiss organising section of the eighth session (Berne 1910) and delegate of the Federal Railways at that session;
Reporter to the Rome Congress (April 1922).

We have been deeply grieved by the news of the death of Mr. Otto Sand, who died suddenly on the 18 December last.

Mr. Sand, who had always taken a great interest in the work of our Association, was appointed reporter on question III (Special steels) in the programme of the Congress which was to have been held in 1915. The report which he compiled for that session was not able to be published in the English edition of the *Bulletin* before the war (1).

After the reconstitution of the Association, Mr. Sand again undertook to compile a report for the Rome Congress. The supplementary report which he wrote on the same subject has also appeared in our *Bulletin* (2).

Mr. Sand was born at Saint-Gall on the 8 April 1856.

Entering the railway service early in life, he became one of the principal technical officers of the largest Swiss railway, to which he rendered services that will long be remembered.

His name is associated with all the important constructional works carried out by the Federal Railways since their coming into existence, among which may be mentioned the reconstruction of Basle station and the enlargement of the stations at Saint-Gall, Vallorbe, Lausanne and Bienne.

He took an active part in the negotiations in connection with setting out of the railway on the left hand shore of the Lake of Zurich, it previously having been confined to the right bank and he supervised the construction of the Ricken Railway, the new line to Hauenstein and the Lake Brienz Railway.

His attention, however, was especially given to the Simplon Tunnel, which was begun by the Jura-Simplon Railway and finished by the Federal Railways. He took a leading part in the construction of the second Simplon Tunnel.

Mr. Sand was a member of the Swiss Commission for investigating electric traction, and he collaborated in the introduction of this new method of working.

He did not shrink from any task however onerous it might be, and he often devoted even his leisure time and holidays to visiting technical works, in order to broaden his views and to gain information profitable to the Federal Railways.

The funeral, at which a large number of his friends and colleagues were present, took place on the 21 December at St. Paul's Church, Berne.

We offer to the family of our lamented collaborator our most sincere sympathy.

The Executive Committee.

(1) See the *Bulletin of the International Railway Association* for September 1920, p. 563.

(2) See the *Bulletin of the International Railway Association* for August 1921, p. 1103.

CORRIGENDA

Bulletin of December 1921 :

Page 2145, « West Jersey & Seashore Railroad », 4th column, 1921, mileage : track, line 3 of the top, *instead of:* « 160.38 », *read :* « 150.38 ».

Page 2145, « Pennsylvania Railroad » : « Paoli & Chestnut Hill », 4th column, 1921, mileage : track, line 18 from the top, *instead of:* « 224.77 », *read :* « 117.40 ».

Page 2147, 1st column, « Norfolk & Western Railway », lines 3 and 4 from the top :

	instead of:	*read :*
Mileage : *b*) Track miles : Main line. . . .	82.60	58.26
Yards and sidings .	25.66	50.00

Page 2147, 2nd column, « Pennsylvania Railroad » : « New York Terminal », lines 13 and 14 from the top :

	instead of:	*read :*
Locomotive miles per year : Passenger . .	820 372	Passenger (including small amount freight) 1 469 343
Freight . . .	549 325	

Page 2147, 3rd column, « Pennsylvania Railroad » : « Paoli & Chestnut Hill », line 4 from the top :

	instead of:	*read :*
Mileage : *b*) Track miles : Yards and sidings .	117.4	10.03